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ABSTRACT

Designed to assist in the on-going process of curriculum development, this report offers science teachers ideas and strategies to help meet the current needs of their students and the demands of society. It is meant to serve as a source of practical suggestions that address the aims set out by Great Britain's Association for Science Education in the document, "Education Through Science." Contents include: (1) planning for change (reviewing perspectives on curriculum change); (2) framework for curriculum development (providing directives for setting and classifying objectives); (3) organizing the teaching of science (focusing on learning strategies, curriculum models, and timetable frameworks); (4) progression, continuity, and community (addressing needs for early experiences, interdisciplinary studies, and courses linked with the community); (5) whole curriculum perspective (advocating a holistic coordinated approach across the curriculum); and (6) perspectives on the need for change in the science curriculum. Bibliographic notes are included. (ML)

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PLANNING

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in the

CURRICULUM

A REPORT AND DISCUSSION DOCUMENT
prepared by a working party on

CURRICULUM MODELS FOR SCIENCE 5 - 16

for the Education (Research) Committee
of the Association

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FOREWORD

The consultative document Alternatives for Science Education was published by the Association in 1979. This stimulated much discussion among members, about the Association's policy on the place of science in the school curriculum. Reports from the Royal Society and the Department of Education and Science encouraged even wider debate.

The Association published its policy statement, Education through Science, in 1981 and the next step now required is the implementation of the agreed policy. The Education (Research) Committee established a working party to show how the policy can be turned into practice; the product of their labours is this report.

While it would be presumptuous to believe that these are the only models which fulfil the criteria in the policy statement, planning a curriculum is not an easy task and we hope that this document will prove useful. We need to review curricula constantly to make the best provision we can for our pupils. As a group of people we teachers are sometimes over-cautious, often resenting change. Evolution, preserving only the best features and adapting to the changing needs of modern society, is essential if our curriculum is not to become fossilized. I hope that this report will be widely read and then acted upon with exciting innovatory results leading to a good provision of "Science for All".

The Education (Research) Committee is indebted to the members of the working party, who have put an enormous amount of time and effort into producing this report.

E.L. Passmore
Chairman, Education (Research) Committee

ACKNOWLEDGEMENTS

The working party wish to thank all people who have assisted with the report.

In particular we would like to thank Professor Malcolm Skilbeck for his constructive criticisms and suggestions and Cathy Wilson and Betty Preston for their comments and perseverance with some very rough drafts. We are grateful to Richard Turner and Headquarters staff for their assistance.

In addition to the above many schools, individuals and authorities have contributed information confidentially to the working party. We would like to make it clear that we have taken all information on trust. It has not been in our brief or within our resources to evaluate this information. It is also important to stress that the co-operation was essential for the working party to make any progress and describe present practice. We therefore would wish to thank the following teachers and schools:

Abbey Woods School, ILEA
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INTRODUCTION

This publication is concerned with the development of the science curriculum in schools. It is based on successful practice which has been placed into a framework in order to provide science teachers with ideas and strategies for curriculum development in order to respond to the specific needs of young people and to the needs of society. It comes from a direct response to the Association's policy document, Education through Science, which states in its preface that: "The publication of Education through Science should not be seen as the culmination of the policy making process but rather as the beginning of a further stage of development. We have not attempted to provide a single prescription for science education and if this document is to be a stimulus for reform, it must be supplemented by a diversity of curriculum models to illustrate the guidelines set out". Association policy will remain rhetoric unless it is translated into action in the classroom (or laboratory!).

Over the past two years the working group has explored strategies which teachers can use to plan for science in the curriculum and the considerations have gone beyond the traditional boundaries of the science department since the learner encounters scientific experiences across the whole curriculum. The challenge has been to develop strategies that will enable "science across the curriculum" to be implemented.

During the life of the working party new opportunities and challenges have emerged. TVEI is now well established although it has not been possible to take account of its effect on curriculum planning. The number of policy statements and memoranda, both national and local, has steadily increased and placed fresh demands on and brought new responses from schools.

The Secondary Science Curriculum Review, of which the ASE is a joint sponsor, has set out aims for science education which are entirely compatible with ASE policy. The resources of the SSCR while not unlimited are considerable. Within its framework many science teachers are developing curriculum materials and plans. This report should be seen as yet a further contribution to the development of the science curriculum.

The changes that have occurred in the educational world reflect a time of change and uncertainty in society as a whole. The future employment prospects are, at the least, uncertain. In a time of economic recession there is a sharp focus on education. This is not just about the allocation of money but also the purpose and value of that education. In this atmosphere teachers are expected to increase the scope of their professionalism eg. the enactment of policies on multicultural education, introduction of vocational courses. This enhancement of the professionalism of teachers is to be welcomed but it requires two main things:

1. Teachers must take on the roles of curriculum planners and developers if they are to maintain control of teaching and learning. This requires more sophistication and expertise than is within the experience of many schools.

2. The demands on people, time and resources will be considerable if this professionalism is to be realised.

This document cannot supply all the answers but it does represent the views of a number of experienced science teachers and other educationalists. The intention has been to present some feasible practical ideas which could achieve the aims set out in Education through Science.

There are issues, such as assessment, which have not been explored because of the lack of time. The working group are also aware that there are different perspectives to curriculum planning and development. The intention is that the strategies and examples outlined will be useful and understandable so that teachers are stimulated into reviewing and changing their practice.

Curriculum planning and development present an exciting opportunity for teachers to realise part of their professional responsibility. This document raises issues and considers possible solutions but it does not supply a prescription for science in the curriculum. The working group feel that it is important that each science department constructs the solution appropriate for its students, its school and its community. This report can serve as a consultative document and act as stimulus for the Association to formulate a broad policy on how science should be learnt in the future.

CHAPTER 1

PLANNING FOR CHANGE

Introduction

The arguments for revising the school curriculum have been catalogued elsewhere and, although we shall be referring to many of them in this discussion, it is not our intention to provide a detailed and exhaustive review. Our brief is to formulate ways of changing the approach to science education so as to reflect the proposals for curricular change made in the ASE policy statement, Education through Science, against a background of rapidly changing national needs, social, cultural, economic and attitudinal changes and the need to plan for an uncertain future. We recognise that in many schools the science curriculum and associated pedagogy have undergone radical change. In other schools there is constant readjustment to take account of modern ideas in the continuing effort to improve the effectiveness of the teaching. Moreover we must beware of condemning traditional content and methods merely for the sake of change. Science education in Britain has a proud heritage and, while recognising the necessity for change to meet the needs of a changing economy and society, we must not forget the lessons of the past. Thus in making proposals for change we intend to draw extensively on current good practice and there are a number of issues to be considered which are discussed below.

Science in a Technological World

Science is a major contributor to modern technology and we believe that science as a part of liberal education should be studied in a technological context. Students need a scientific and technological perspective to enable them to make sense of the world around them. (See Chapter 3). It is arguable whether the disciplines of sociology, economics and politics should find a place in school science, but we would maintain that they should have a place somewhere in the core curriculum of all schools, that they are relevant in a scientific and technological context, and that science education should not be insulated from them. We hope that science will be studied not only as a self-contained intellectual discipline but as part of our culture.

Balanced Science for All

Children in primary schools are entitled to a science component in their education, integrated with the total curriculum. In most secondary schools students already study a fairly broad spectrum of science until the age of fourteen, but they then encounter "the option system" which distorts the balance of science education. Between 1975 and 1978 the Secondary Survey (Aspects of Secondary Education in England and Wales) showed that about one student in eight studied no further science after the third year. It is probable that this situation has improved since then. More significant however in the context of this discussion is that more than half the students (55%) studied only one science subject for their last two years of compulsory education and a small number (7%) studied all three major sciences - physics, chemistry and biology. Both these groups received an unbalanced education, the first group because the study of either biological or physical science concepts had been neglected, thus limiting their scientific perspective, and the second group because their science education occupied too big a proportion of curricular time, thus limiting their study in other important areas. Moreover, although the remaining 25% spent about the right amount of time on science, their science education was also unbalanced in most cases because of

rigid compartmentalisation into the three traditional sciences, one of which was not being studied. This early specialisation precluded for many the further study of science and may have seriously curtailed career choices. Lack of balance and breadth leads to lack of flexibility. The next generation of citizens, including future technicians and researchers, will need to be versatile, probably changing career two or three times during their working lives. This sort of development is inhibited by the present emphasis on analysis, criticism and the acquisition of knowledge. More time should be spent teaching relevant skills, encouraging flexible attitudes and preparing for life outside the educational system. Not only would such education for capability improve the quality of life of individuals, but it would also bring significant benefit to society in economic terms. Balanced science for all should be part of the minimum educational entitlement and this includes the opportunity for individuals to study what is relevant for them and to reach standards appropriate to their ability. This is the kind of approach that is being advocated by the 'education through capability' movement.

The Influence of the Examination Boards

The examination boards are frequently blamed for the inertia that is too often apparent in our curricula and teaching styles. There is an element of truth in this allegation. Certainly the influence of and importance attached to external examinations at 16+ are greater than in most other countries. Indeed many countries, including all other countries in Western Europe, seem able to manage without formal external examining at all for this age group. However it should be remembered that the examining boards derive their power solely from the respect accorded to them by society, not least the teaching profession. On the other hand the boards claim, quite justifiably, that the style and content of their syllabuses and examinations are controlled to a very considerable extent by schoolteachers. It is therefore difficult to avoid the conclusion that external examinations too often provide a convenient and comfortable excuse for resistance to change. Reform can be brought about without abolition of external assessment and this has been demonstrated by some, though not all, mode 3 courses and also by the examinations set for a whole range of special projects. Nevertheless, for whatever reasons, most current examination courses stress the importance of knowledge and comprehension of a very limited range of science. The applications of scientific concepts and the processes of problem solving are generally given scant prominence as are cultural or historical contexts. Syllabuses, while overloaded with detailed content, are at the same time ignoring important areas of content such as earth sciences, astronomy and cosmology, psychology and the other human and social sciences.

There is a need for assessment reform and in principle the idea of drawing up national criteria for examinations at 16+ is welcome. At the same time there must be serious reservations about some of the assumptions which are being made and the mechanism by which the criteria are to be established. Inclusion in the curriculum of socioeconomic and political issues in science education, especially the physics element, are still problematic and integrated science has an unjustifiably low status in some quarters.

The Role of the Independent Schools in Curriculum Development

There is a real danger of the independent sector becoming isolated from the mainstream of educational progress, a prospect which we believe it would not welcome. The independent schools in this country have traditionally played a prominent role in curriculum development and this involvement was particularly noticeable during the development of the early Nuffield schemes in the 1960s. At that time most young people being educated in the state system attended either secondary modern schools or grammar schools from the age of 11. The

perceived aims of the independent schools and the grammar schools were virtually identical. They were educating an academic elite to serve the community. They were humane and altruistic institutions and the emphasis on service was (and is) pre-eminent. The privileged status of their successful students was openly acknowledged and seen as essential in enabling them to serve society effectively.

It was a paternalistic philosophy. The student population of both types of institution was fairly homogeneous in terms of intelligence, social background and expectations. The grammar schools provided, in theory, equality of opportunity within the state sector, selecting pupils purely on the basis of intelligence and intellectual promise. In practice, although the grammar schools did marginally affect social mobility, their intake came predominantly from the commercial and professional middle classes. The public schools did not see the grammar schools as a threat. The former also favoured social mobility, albeit in terms of offering entry to a privileged establishment, the new entrants then being expected, and indeed trained, to conform with establishment norms. As long as established grammar schools existed in most parts of the country the collective social conscience of the independent sector could rest easy. It is noticeable that, with the advent of comprehensive education for 85% of this country's children, the public schools, with or without government assistance, have striven to provide more open access. The criterion for selection, as in the old grammar schools, is promise of academic excellence.

Because of the homogeneity of their student populations, the two types of school both developed very efficient and successful subject-centred methodologies. The teachers were highly qualified subject specialists, believing in the job they were doing and willing to make not inconsiderable personal sacrifices in the interests of their students. There evolved a qualifying structure, the GCE Boards, which provided measuring instruments to assess objectively the achievement of pupils in terms of the educational aims of the schools and the more or less uniform pedagogic style adopted. When the curriculum development movement, thought very progressive if not revolutionary at the time, arrived, the examination boards co-operated enthusiastically. The system had not really changed however; the target group was the same and their education remained subject orientated and very academic. All assessment aimed to be totally objective and because the affective domain was believed to be unassessable in these terms it was ignored by the boards and inevitably took second place to the cognitive domain.

Most of the grammar schools have now gone. The comprehensive schools reflect greater cultural diversity and therefore have much more heterogeneous population. Schools are increasingly finding that they cannot effectively teach their most able students in isolation from the rest of the social and ability range. The teachers' responsibilities, taken as seriously as ever, are broader and a totally new educational philosophy is therefore evolving. This process is discussed more fully in Alternatives for Science Education.

It is to be hoped that the independent schools will take at least a passive interest in the new curriculum movement because, when the examination system changes to take account of the needs of the majority of the population, the independent sector could be left isolated from the maintained sector. It would be preferable for them to participate positively as in the past, offering their influence and their considerable resources and good will.

Science in the Primary Schools

There are many excellent primary science programmes operating within a cross-curricular framework. Indeed their lively open-ended approaches are in sharp contrast to the sterile, examination-oriented courses seen too often in

the later years of our secondary schools. Children of primary age are usually avid collectors and the best primary schools capitalise on this quality and strive to develop it.

The children are introduced to the basic scientific process of classification (preferably by systems which they have derived themselves), looking for patterns and generalisations, forming hypotheses and testing them. Courses are based on the local environment and start within the experience of the children. They are thematic or project based (see Chapter 3), often using as starting points questions raised by the children themselves. There is much emphasis on group work and problem solving. Project work is done by children co-operating within a group, the teacher acting as a member of the team and keeping a fairly low profile. He or she needs to be very sensitive to the needs of individuals and their state of development, judging the moment for moving to the next stage of an investigation or the readiness of a child to be introduced to a more challenging approach. The teacher has to be aware of the temptation to offer "the correct answer" or to correct a child's early hypothesis even though it may explain perfectly adequately the data available and the patterns discernible at the time.

The lack of laboratories, a wide range of equipment and specialist teachers is not a disadvantage when working with this age group because it is even more important at this stage than later for science studies to be an integral part of the curriculum and not seen as an isolated, esoteric pursuit. The ASE has done its best to encourage the sort of approach described above by, for example, the publication of primary science newsletters. There is much that secondary school science teachers can learn from the adventurous and experimental pioneers in the primary sector. If all primary school pupils had access to the kind of scientific experiences described above it would become much easier for secondary teachers to remodel their courses in accordance with the aims listed in Education through Science. There are however two fundamental problems.

The first of these is that, in spite of the advances made in recent years, there is still a large number of primary schools without effective science programmes. The HMI Primary Survey, and the 9-13 Middle School Survey, both published in 1984, show that provision tends to be either very good or virtually non-existent. The latter stems largely from lack of confidence by the teachers. Such teachers believe themselves to lack the necessary expertise, although all that is really required is enthusiasm and a belief in learning through experience and pupil-based enquiry. They are victims of their own education, which emphasised the mystique and the inaccessibility of science. This problem is slowly being overcome by the publication of well-presented resource material, in-service training designed to instil confidence and the appointment of advisory teachers as primary science consultants. It is important that science in the primary schools should be an integral part of the curriculum.

The second problem concerns the response of the science specialists in the secondary schools. It is a problem of liaison and communication, a lack of awareness of the general philosophy of primary science and of the particular programmes in individual feeder schools. This is compounded by the fact that secondary schools may recruit children from several primary schools with a wide range of provision. The situation becomes even more complex when there is a three-tier system, with middle schools, where this type of interface problem may occur twice. This is an issue which is taken further in Chapter 4.

Curriculum Change through Negotiation

For changes in the science curriculum to be genuine and lasting, they must be negotiated and agreed by a number of different agencies and institutions. The

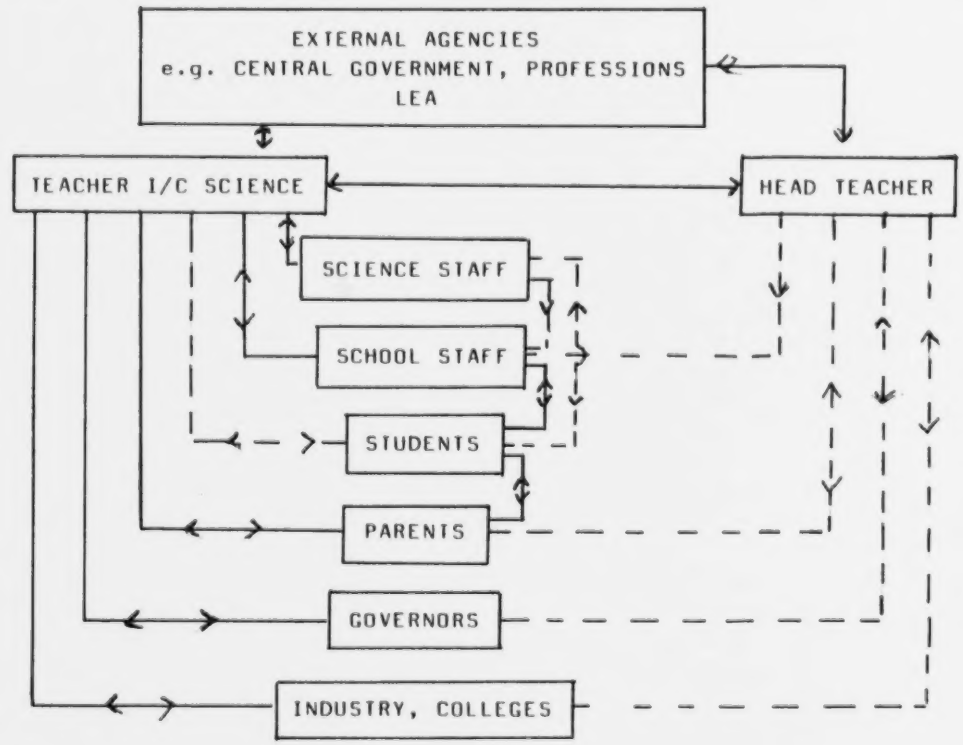
negotiation process has three stages:

(i) Pinpointing the areas of concern
(ii) Analysing the problems and suggesting solutions
(iii) The implementation process

Principal agencies are the local education authorities and the schools themselves, (although hitherto the examination boards have exercised a major but subsidiary role). Throughout the three stage process there are many organisations who are entitled to consultation and the chance to influence change - industry and commerce, through both management and trade unions; professional and academic societies; higher and further education and the community, especially the students themselves and their parents. The first stage of this process should by now have been completed, although there may well be schools in which this is not the case. The preliminary talking has stopped and the action is beginning. The second stage is well under way, both nationally and locally. The ASE, together with the Schools Council, has already produced a document, Decisions in the Science Department, on management of the implementation of change. Decisions in the Science Department also aims to contribute to the process of change by providing a selection of alternative curriculum models based on work already taking place in schools.

The importance of a structure or framework for consultation, negotiation and implementation in schools where curriculum change is envisaged has already been emphasised. Two possible frameworks for this process cover most possibilities although various other combinations and modifications are possible. The first framework is centred on the role of the head of department with the head teacher acting in an advisory and consultative role. (See Box 1.1)

Box 1.1



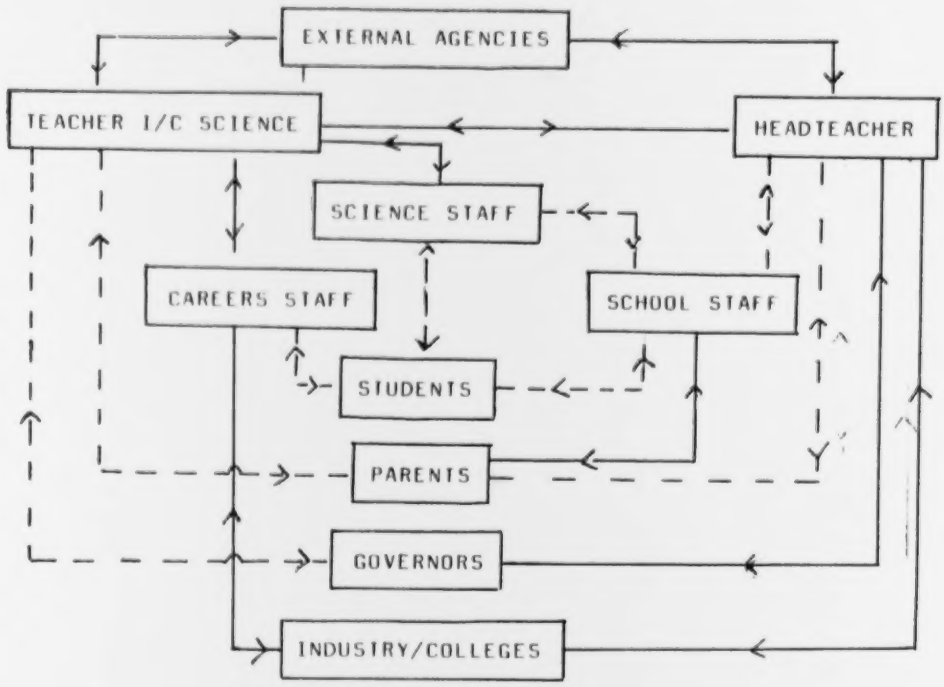
KEY: ———— Formal Relationship

--------- Informal Relationship

It provides a simple and clear-cut mechanism but makes great demands on the head of department and involves more delegation of power than some headteachers might consider appropriate. In particular, it is doubtful whether headteachers would be willing to delegate their role of reporting to their governing bodies or indeed whether governors would be happy to accept such an arrangement.

The second framework allocates managerial responsibility rather more widely while still keeping the head of department in a central position. (See Box 1.2)

Box 1.2



It is a more democratic structure and lightens the load on individuals. In both cases the roles indicated for the headteacher could be shared amongst a senior management team of head and deputies.

Whatever the management structure of a school, if it is to implement a policy of "science for all", somebody will have to take responsibility for managing staff and changing attitudes where necessary. The strategies adopted will depend upon resources and the attitudes, special interests and skills of the teachers concerned. Appropriate strategies will therefore differ from school to school but experience has shown that success depends upon detailed consultation with all concerned, shared responsibility and corporate developmental processes.

Initiators of Change within the School

It is important in both primary and secondary schools that there is coordination of science education across the curriculum. This is more difficult in

secondary schools, because of the compartmentalisation of the curriculum into subject areas, but science education in the broadest sense is unlikely to be confined to the boxes on the timetable labelled 'science'. A curriculum overview is essential, together with periodic reviews and perhaps restructuring. This clearly requires the understanding and support of head teachers and considerable tact and political skill on the part of the middle management. The latter must be prepared to give, in the appropriate forums, clear expositions and rationalisations for redefining science education and must be able to suggest ways in which the necessary cross-curriculum links can be created and maintained. (See Chapter 5).

Heads of Departments

In most secondary schools the heads of department play a key role in the implementation of change. It is they who are responsible for structuring and organising their departments so as to interact harmoniously and effectively with the overall ethos of the school. (See chapter 5). It is they who mediate with the head and senior management team, other departments, pastoral and support staff.

Some have more autonomy than others but, whether or not they make curricular or management decisions themselves, they should certainly influence the decision-making process in the school. It is also the responsibility of heads of departments to interpret school and departmental policy to colleagues in their departments, to motivate then and to plan for staff development. (See Chapter 2).

Science teachers in the secondary sector will have had an extensive formal scientific education, usually confined to a single discipline. Often they will resist change because they prefer to work within their specialisms. They rationalise their conservative approach in terms of the external constraints exercised by examination boards and the tertiary sector and the perceived desires of students, parents and potential employers. Such attitudes tend to lead to a preoccupation with the teaching of knowledge and skills within traditional scientific contexts at the expense of processes, applications, cultural, historical and sociopolitical implications and a broadening of contexts.

Posts of special responsibility (Post holders)

The term 'post holder' is the primary equivalent of head of department, but the situation in primary schools is usually different. These schools tend to be small and consequently the management structure is more tightly drawn. The teachers are polymaths, although schools that have taken an initiative in formalising policies on the teaching of science often have a post holder in charge of science. The post usually carries the status of a scale point. As we have already pointed out the main constraint on individual teachers is likely to be lack of confidence. They may accept other authorities on the nature of science in an unquestioning way and undervalue the expertise they themselves have already developed in other subject teaching areas such as problem-solving, experimentation, observation and communication. These skills are not always recognised by primary teachers as part of the scientific process.

Governing Bodies

School governors now share with their local education authorities a very clear statutory responsibility for the curriculum. If they are wise they will seek the advice of the professionals employed in their schools and will probably delegate detailed responsibility for curriculum planning. However, teachers should be in no doubt that they are accountable to their governors as representatives of the community, and can, at least in theory, be overruled by them on curriculum matters. Full and clear information and careful consultation about planned changes and their intended consequences are therefore the least that governing bodies should expect. These bodies rightly contain a

cross-section of society; their members may have conflicting interests and diverse expertise. Proposals for curriculum change and reports on the progress of curriculum development therefore need very careful presentation and this should be a matter of professional pride.

Students

Above all it should be remembered that the group with the biggest stake in education is the students themselves. They too are entitled to consultation and a clear rationale for the curriculum. The consultation is by its very nature usually informal but students are less likely than they were to accept unquestioningly the curriculum set before them by their teachers. Disaffection with the curriculum is a spur for change and a negotiated curriculum will increase the sense of purpose shown by the students. We should welcome and respect the increasing sophistication and independence of mind of our young people.

Initiators of Change from Outside the School

So far we have considered the constraints on and the opportunities for change arising within schools themselves. There are also external agencies exerting powerful influences. These cannot be considered in isolation from the internal constraints because there is a complex interaction. Indeed external agencies often stimulate internal pressure for change and this is especially true at the present time. Schools which do not start voluntarily to consider their policy for science education may well find themselves compelled in the not too distant future to undertake changes for which they are not prepared.

Local and Central Government

Under the (quite proper) influence of politicians, the Department of Education and Science is now taking a much more positive interest in the determination of curriculum policy. Detailed guidelines for LEAs and schools have been published as in circular 6/81 and, although these guidelines are not mandatory, authorities are now required to be aware of the policies of their schools and to draw up and publish detailed aims and proposals for their implementation. Individual schools must publish certain information including external examination results and must draw up, in consultation with their governing bodies, aims, objectives and proposals for implementation in all subject areas. Schools no longer possess the degree of autonomy they once had. They are required to be accountable to government and to the communities they exist to serve. At the very least they must devise rational policies, make them public and be prepared to defend or modify them. It is to be hoped that the curriculum will be continuously reviewed and periodically updated and restated at both school and LEA level.

The Professions and Higher Education

The Royal Society and other learned societies and professional institutes have views on the school science curriculum which demand respect but their statements are intended to influence national and regional policy rather than individual schools. Likewise the universities influence the schools in a variety of ways but perhaps most effectively through the examining boards. They speak collectively through that powerful body, the Standing Conference on University Entrance (SCUE). More and more students take up further education or training, either full-time or part-time, on leaving school. The Further Education Unit has published guidelines on prevocational education. It has little to say explicitly, however, about science.

Industry and Commerce

The views of employers and industrialists on the kind of education schools should provide are confused and contradictory. There is general agreement on the importance of simple mathematical skills and on verbal and written communication but no very clear consensus on precisely what these entail in

educational terms. There is strong support from the CBI and other national representatives of top industrial management for the development of problem-solving skills at school. This is clear from their responses to Alternatives for Science Education and subsequent discussions. Unfortunately, local personnel managers, (those who make decisions about employing young school leavers), may not have the same attitudes. They, together with colleges of further education, seem to give undue weight to formal examination qualifications in traditional science subjects, especially physics, and to factual recall of information. This is partly the fault of the schools for not adequately communicating their aims, philosophy and methods.

This sort of communication between schools and employers is especially important at times of curriculum change and its subsequent implementation. Middle managers in schools are potentially the best communicators in this field but they are unlikely to be able to find time for protracted negotiations. It may be that negotiations need to be conducted through an intermediary - head teacher, careers teacher, science adviser or LEA careers adviser. The SATROs too can be very useful agents for communication between schools and industry.

Parents

Consultation and negotiation with parents is crucial, not only because they have a right to be fully informed but also because they have a vital supportive role to play in their children's education. They cannot be expected to negotiate effectively unless they understand and believe in the school's educational policy, its aims and methods. Information-giving and discussion can take place at meetings with groups of parents or perhaps more informally at school or departmental open evenings. Such events do not preclude individual interviews with subject and pastoral staff. Such contacts will not, of course, be made exclusively by science staff and so it is essential that colleagues are briefed and understand the department's policy and methods.

Resourcing Change

The Association for Science Education supports the principle of accountability and wishes to see educational standards maintained and, wherever possible, improved. It seems necessary, however, to reiterate the truism that standards must be closely related to the support and resources provided for the schools. Effective change can only be brought about if a number of resource conditions are fulfilled.

(a) There needs to be a national programme of research and school based curriculum development. Ambitious initiatives such as the Secondary Science Curriculum Review, the Microelectronics Education Project and the Technical and Vocational Education Initiative are important. They are likely to have dramatic and far-reaching effects.

(b) A major review of initial teacher training is also needed and this should include a carefully planned and supportive induction programme. Attitudes and skills implanted at this stage may become institutionalised and inimical to change. Today's science teaching force is relatively youthful and that, together with the problem of falling rolls, means that there will be very few new teachers for several years. A structured INSET programme is also urgently needed to equip serving teachers with the necessary knowledge and the new attitudes and skills to cope with the changes expected of them. This initiative can only achieve maximum effectiveness if it is supported by LEAs in two ways: adequate arrangements should be made to release teachers to attend courses and to ensure that their work is properly covered during their absence, and LEAs should ensure that proper procedures for staff development are established in each

of their schools. Professional development of staff should be continuously monitored in the light of personal needs and the changing demands of the school and the department, and appropriate use should be made of national and local courses and school-based in-service training. The internal monitoring process should be coordinated by LEA advisory groups comprising advisers and teachers. In-service training must meet the needs of the specialist science teacher (updating, new teaching techniques, changes in the aims and philosophy of science education) as well as more general pedagogic needs.

Summary

In this chapter we have argued for a broad and balanced science education for all. We see a need for more coordination of the science taught in primary and secondary schools and we are also anxious that independent schools should not become isolated from the mainstream of state education. Curriculum change is needed but it can only be effectively achieved by negotiation with agencies both within and outside the school system. Middle managers have a key role to play in this process. Moreover, changes will not be successful unless adequate resources are made available and used effectively. Both initial and in-service education and training urgently need reviewing and restructuring.

All this has clear implications for LEAs and the education service in its national context for facilitating the initiation and implementation of curriculum change, but the ultimate responsibility lies with individual schools. The list of questions in the box on the opposite page provides a possible check list for teachers planning changes. It complements the flowsheets shown in Boxes 1.1 and 1.2.

Box 1.3

Questions for teachers planning change

A. In preparation of initial draft proposals

1. Are you aware of the guidelines for science education from the following bodies?

   DES
   HMI
   ASE
   Royal Society
   Secondary Science Curriculum Review
   Schools Council
   School Curriculum Development Committee
   Secondary Examinations Council

2. Do you know if your LEA has made a policy statement about science education?
3. Are you aware of the views of local industry and commerce on science education?
4. Have you discussed the need for change with your headteacher?
5. Have you discussed the proposed change with your colleagues in (a) the science department and (b) other departments?

B. Consultation on the initial draft

1. What procedures are to be used to present the proposals to the rest of the staff?
2. How are you going to convince staff that the aims are appropriate?
3. Do you know how to present your plans to the governors?
4. What opportunities are there to present your plans to parents?
5. What opportunities are there to present your plans to local industry and commerce?
6. What opportunities are there to present your plans to local colleges of FE and HE?

C. Preparation of final draft

1. Have you decided what priority should be given to the views of the different groups which you consulted?
2. Have you examined the constraints which are present in your school?
3. Do you wish to involve other members of staff in the drafting of the final plan?

Once a plan for a school and department has been formulated with the initial consultative process completed and the strategic decisions made - the science department must get down to the details of organisation and this is the subject of the subsequent chapters.

CHAPTER 2

A FRAMEWORK FOR CURRICULUM DEVELOPMENT

Introduction

This chapter explores the nature of scientific and technological knowledge and at this stage it may be helpful to reaffirm the overall aim of Education through Science. This emphasises not only the pursuit of knowledge for its own sake but also:

- relating that knowledge to the whole of our culture
- applying it to real problems

These horizons for science education are wider than they have traditionally been and have implications not only for the delineation of the boundaries of science education itself, but also for the interrelationships between science and other subject areas of the curriculum. Science education can no longer justify itself solely on the grounds of insular academic integrity.

Relating knowledge to culture

Science penetrates cultures and is part of them. (The thinking of our scientists has followed, led, and been a part of, the philosophies of our societies for thousands of years.) Cultures have called on science to provide the answers to questions about origin and destiny. The connection with our culture prompts us to be critical of our aims for science education. In formulating new aims that relate to culture a first stage might be to ask questions about:

- the nature of a society with complex political economic and social structures
- the role of science in forming our view of the world
- the nature of technology
- the nature and range of communication
- the nature of commonly held beliefs and values
- the value of aesthetic experiences

It is likely that this analysis would reveal a need to include such aspects of education as:

- vocational: preparation of young people for adult life
- social/moral: preparation for citizenship
- personal: preparation for self-sufficiency (and leisure)

Applying knowledge to real problems

The application of science involves a wide variety of process skills which are both intellectual and physical. Some real problems will involve students in finding out information they do not already possess, through first hand investigation resulting in 'discovery'. Other real problems are not so much

scientific as technological, involving the creation of a device or system that will fulfil a human need.

Gaining an Overview

It is necessary to gain an overview of what is taught, and why. Teachers must explore the totality of students' learning experiences in science, classify these experiences and relate them to each other within some coherent framework or model for science knowledge. This must take place in the context of agreed school policies and lead to school-based curriculum development. The Skilbeck model for school-based curriculum development is one approach to achieving a coherent framework. (See Box 2.1)

Box 2.1 A summary of Skilbeck's situational analysis and plan for school- based curriculum development

1 Situational analysis

Review of the change situation	Analysis of factors which constitute the situation
(a) external	(i) cultural and social changes and expectations including parental expectations, employer requirements, community assumptions and values, changing relationships (e.g. between adults and children), and ideology
	(ii) educational system requirements and challenges, e.g. policy statements, examinations, local authority expectations or demands or pressures, curriculum projects, educational research
	(iii) the changing nature of the subject-matter to be taught
	(iv) the potential contribution of teacher-support systems, e.g. teacher training colleges, research institutes, etc.
	(v) flow of resources into the school
(b) internal	(i) pupils: aptitudes, abilities and defined educational needs
	(ii) teachers: values, attitudes, skills, knowledge, experience, special strengths and weaknesses, roles
	(iii) school ethos and political structure: common assumptions and expectations including power distribution, authority relationships, methods of achieving conformity to norms and dealing with deviance
	(iv) material resources including plant, equipment, and potential for enhancing these
	(v) perceived and felt problems and shortcomings in existing curriculum.

Source: SKILBECK, M (1975)
School-based Curriculum Development and Teacher Education

In order to facilitate real communication with each other all practitioners must acquire a lingua franca. Two key words in the vocabulary which are often misused are 'aims' and 'objectives'. Without a proper understanding of their meaning a clear analysis of the curriculum is impossible.

Aims for learning in Science

Aims involve a statement of preferences, judgements and values about the nature of the educational process. (See Box 2.2)

Box 2.2 A good set of aims is a statement of intent

It states in broad terms what the educational process is designed to achieve. It hints at the totality of experience on offer and outlines possible routes to the desired goals. It is not narrowly prescriptive. Without a good set of aims a school or department is unlikely to have a real sense of purpose. To judge the quality of the aims there are a number of pertinent questions that should be asked.

Do they really represent a complete overview of what the teaching team hopes to achieve?

Does everybody in the team understand them?

Is the language used appropriate and unambiguous?

Can an outsider observe the aims fulfilled in the classroom?

It is perhaps obvious, but needs to be said, that the aims for science education should reflect the aims of the school.

Ways of selecting a set of aims

Borrowed from published sources

Many published curriculum projects neatly tabulate their aims and sometimes such a set of aims is simply declared to be departmental policy. In certain circumstances this may be a perfectly sensible and respectable thing to do.

Box 2.3

This is an extract from a school's documents in which the origins are only thinly disguised.

"The introductory course in Science has the following aims:

1. To encourage attitudes of curiosity and enquiry.
2. To introduce the art of planning a scientific investigation by encouraging the pupil to ask questions, design experiments and assess the evidence.
3. To help pupils to express their ideas and discoveries in a simple but accurate fashion both orally and in writing.
4. To provide a course which reflects up to date thought and technology (what scientists do and can do) and which relates science to the outside world.
5. To provide the necessary framework for the pupils' subsequent studies in the school or elsewhere."

The team may not yet have sufficient confidence or experience to express their own views cogently. Alternatively the head of department may feel that a major change is necessary and that the simplest way to overcome inertia is to use the aims of a tried and prestigious national curriculum development project. (See Box 2.3)

The danger of such an approach is that the proposal does not come "from the heart" and there is therefore little or no commitment to it. It may be merely a cosmetic exercise to relieve external pressure from without, for example from the senior management in the school or from the LEA. If this is the case the aims are valueless and the whole exercise is a waste of time it will not have changed the department's approach to science teaching in the slightest.

Proposed by the team leader

A team leader may decide to ask the team to accept a set of aims which represents a distillation of his or her own thoughts and reading, reflecting personal idiosyncracies as well as views expressed in published material. (See Box 2.4)

Box 2.4

'Through the study and experience of a body of knowledge called science our pupils should acquire:

- knowledge and factual information
- some generalisations, principles and laws which hold good in the physical and living world
- a range of skills, rooted in the scientific tradition, but applicable to life in general
- an understanding and ability to use certain key concepts and basic ideas
- an ability to use scientific knowledge, concepts and processes in the pursuit of (and communication of) new knowledge - in basic terms, the ability to see further by standing on someone else's shoulders

The achievement of the above aims will give our pupils a particular perspective or "way of looking at the world" which complements and balances other perspectives and disciplines, and without which, the individual cannot achieve a balanced general education.'

A statement of this kind may be a valuable tool for professional development if it acts as a catalyst for discussion. In this case there is a much better chance that the aims will be instrumental in promoting change, because the leader will be constantly referring to them in discussion and adjusting practice to reflect them. Thus they will serve to affect staff attitudes and to establish a climate favourable to curriculum development.

Through discussion and negotiation in the team

Another approach is to allow the aims to develop from within the team and for a corporate expression of them to evolve. This is most likely to happen if there has been a continuing debate about the nature of science education. If the team also possesses the skill to synthesise and express its views, a very complete and satisfactory set of aims will emerge. In addition, because the team's commitment to the aims is likely to be high, their fulfilment in the classroom will be observable. By the nature of their origin, they are likely to be more personal than those derived from the other two routes. Such a statement of aims is exclusive to each school (See Box 2.5). Clearly the aims will represent an overview of the team's hopes; everybody will understand them and the language will be appropriate.

Box 2.5

A framework within which they might be developed is illustrated in the following example:

STATEMENT OF INTENT

Our main aim is to make the experience of learning science as open-ended and as enjoyable as possible and to allow pupils more guided freedom in their science lessons. We aim to operate in as flexible a manner as possible, including in our practice a wide range of resources, teaching materials and methods and to have an open mind towards establishing cross-curricular links.

Our aims can be broken down as follows:
Amplification in terms of:-
(i) Aims of the science faculty in general
(ii) Aims for the development of pupil learning
(iii) Aims for the development of experimental skills
(iv) Aims for the personal development of the pupils
(v) Aims for the organisation of learning

Setting Objectives

Whereas aims are broad and non-specific statements of intent, objectives are prescribed goals for the learner. They specify, with varying degrees of precision, intended learning outcomes. Some teachers consider the precise statement of learning objectives to be unnecessary, even a positive encumbrance. Learning objectives are important, however. They describe the routes the students may take and are evidence that the learning process has been planned. Moreover they are the only valid focal points for assessment of the quality of learning that has taken place.

There are several good but different ways of presenting objectives. Highly specific guidelines relating to teaching and assessment can be provided. (See Box 2.6)

Alternatively a more generalised picture can be given while still enabling key elements of the learning process to be made clear (See Box 2.7).

The format used by individual schools will be determined by the precise way in which objectives are to be used.

Classifying Objectives

An all embracing way of classifying learning objectives would be useful. A pattern that seems to satisfy all the different needs breaks science knowledge down into four distinct types. They are:-

- key concepts (or ideas)
- basic skills
- knowledge requiring recall
- attitudes

It is possible to place all the science knowledge contained in any curriculum within these categories.

Box 2.6

AIMS	OBJECTIVES
1 The pupil is able to recall or recognise information which is useful.	Knows common terms Knows specific facts Knows methods and procedures Knows basic concepts Knows principles
2 The pupil is able to extend a principle to a known situation. This includes:-	Understands facts & principles
(a) changing information into a different symbolic form or language	Interprets visual material Interprets charts and graphs Translates verbal material to mathematical formula
(b) discovering relationships between facts, generalisations, definitions, values and skills	Estimates future consequences implied in data Justifies methods and procedures
3 The pupil is involved in the solution of problems. This requires the identification of issues and the selection and use of the appropriate generalisations and skills	Applies concepts and principles to new situations Applies laws and theories to practical situations Solves mathematical problems Constructs charts and graphs Demonstrates correct usage of a method of procedure
4 The pupil is able to solve problems in the light of available knowledge	Recognises unstated assumptions Recognises logical fallacies in reasoning Distinguishes between fact and inference Evaluates the relevancy of data Analyses the organisational structure of a task
5 The pupil is able to solve problems which require creative thinking	Writes a well-organised theme and gives a well-organised speech Writes a creative short account Proposes a plan for an experiment Integrates learning from different areas into a plan for solving a Formulates a new scheme for classifying objects
6 The pupil is able to make judgements of good or bad, right or wrong, according to standards he designates	Judges the logical consistency of material Judges the adequacy with which conclusions are supported by data Judges the value of work by use of external/internal standards

Box 2.7

Students should be able to:

- recall the vocabulary, facts, concepts and patterns necessary to make them scientifically literate, whether for everyday life in a technological world, or for a future scientific or techno- logical career

- demonstrate understanding of the basis of the knowledge referred to in 1, and use it correctly in, and apply it to, new circumstances

- select information critically and arrange it so that a pattern emerges

- use their patterns and additional information to develop solutions to problems

- show their reasoning in making judgements between suggested solutions to problems

- organise their ideas for purposes of communication and communicate ideas effectively in various ways

- recall the social significance of major scientific and technological developments

- show understanding of the complexity of the interaction between science, technology and society, and assess the factors involved

- design simple experiments with the aim of solving a particular problem

- perform simple laboratory experiments

- become accurate and unbiased in reporting their scientific work

- demonstrate constructively their scepticism about suggested patterns

- show a reasoned concern for the application of science and technology within the community

Key Concepts

These are the main scientific ideas to be encountered in a course or unit of work. They cannot be stated in behavioural terms because the depth of understanding will depend upon the cognitive maturity and ability of the learners. (See Box 2.8)

In technology it is insufficient for a concept to assist in explaining things. It also has to help in the decision making processes of design and construction. Some concepts are more technological than others in this sense. For example efficiency and cost effectiveness are concepts which are used in coming to technological design decisions. Some scientific concepts, like thermal conductivity, which relate to ideal circumstances have to be

Box 2.8

A Classification used in one school is given in this example

Of Living Things

Structure
Support
Function
Adaption
Transport
Systems
Food/Digestion
Respiration
Transpiration
Senses
Tropisms
Osmosis
Colonies
Chains
Environment
Stability
Reproduction
Diet
Disease
Plant
Animal
Cells
Growth
Development
Life Cycle
Life
Conservation
Vertebrates
Invertebrates
Variation
Flower
Non-flowering
Genetics/Heredity
Photosynthesis
Fossils
Evolution

Material
Matter
Air
Burning
Solid
Liquid
Gas
Oxygen
Reactions
Reactivity
Water
Purification
Atomicity
Particles
Acids
Alkalis
Metals
Non Metals
Density
Molecule
Mass
Separation

Of Physical Things

Phenomenological
Structure
Action/Reaction
Colour
Light
Electricity
Current
Voltage
Resistance
Insulation
Conduction
Identification
Relationships
Stability
Measurement
Length
Volume
Units
Refraction
Reflection
Magnetism
Radiation
Equilibrium
Charge

Energic
Heat
Energy
Movement
Force
Speed
Waves
Conservation
Forms of Energy
Sound
Light
Weight
Gravity

modified to meet the exigencies of reality. The architect is more concerned with thermal transmittance values of building materials than with their thermal conductivity.

Box 2.9

A useful framework on which to base this structure of concepts is taken from the Assessment of Performance Unit publication on Understanding Design and Technology.

The essence of an understanding of design and technology lies in three groups of technological concepts - control, energy, materials. To exercise control over the man-made environment it is necessary to know how static or dynamic systems can be created for a specific purpose. As energy in some form must be involved, knowledge is required of sources, costs and forms of energy, of methods for storing and transmitting energy, and of efficiency and the conversion of energy. Similarly, as design involves the selection and use of appropriate materials, knowledge is also required of their sources and costs, of their useful properties and limitations, and of the appropriate methods by which they may be processed, manipulated and connected.

If concepts are to be used in design decision making as well as in explaining things, they must include their technological forms or interpretations. (See Box 2.9)

Basic Skills

These are the skills used in the processes of scientific enquiry (scientific skills) and in the processes of creating something which will meet a human need (technological skills). (See Box 2.10)

An alternative way of categorising skills could be to start with the processes and then to pick out those skills pertinent to science. (See Box 2.10)

Box 2.10

Scientific and Technological Skills

(LS)Laboratory Skills

Apparatus handling
Apparatus identification
Apparatus assembly
Apparatus usage
Safe practice
Sharing/Caring
Apparatus production and adaption

(OS)Observation Skills

Making observations
Recording observations
Interpreting observation
Selection of relevant observations
Sampling

(RS)Reporting Skills

Verbal reporting
Written reporting
Use of symbols
Graphical representations

(MS)Measurement skills

Measurement of length
Measurement of area
Measurement of volume
Measurement of mass
Measurement of other quantities
Application/use of units
Reading meters
Design/use of scales
Use of measuring instruments

(PS)Process Skills

(PSS) SCIENCE - 1

Experimental design
Experimental investigation
Hypothesis generation
Interpreting results
Looking for patterns and relationships
Drawing conclusions

(PST) TECHNOLOGICAL

Problem identification
Solution
Testing solution
Interpreting test results
Modification skills

(PSG) GENERAL

Critical reasoning
Applying appreciation
Contextual appreciation

Box 2.11

Pupils should be able to:

- pose problems
- select information critically and arrange it so a pattern emerges
- use their patterns and new information to develop the solutions to problems
- design simple experiments with the aim of solving a particular problem identifying and controlling variables
- make reasoned judgements between different solutions to problems
- judge evidence
- recognise the tentative nature of generalisations, criticise and modify them in the light of new evidence

Some skills are more specifically, though not exclusively, scientific than others:

- manipulation
- analysis and the interpretation of data
- selection of observations and data
- measurement
- classification
- observation, noticing relevance
- use of instruments

There are other skills that are as important in science as in other subjects, but are often not emphasised in science courses:

- language
- mathematical, including the symbolic representation and understanding of data
- study

Science and technology education is primarily about helping young people to take part in science and technology activities. Participation requires a complexity of interrelated intellectual and physical skills which cannot be taught individually in isolation. Their development is not to be left to chance. Teachers need to evolve a systematic approach to structuring skill development and to relating it closely to their concept developments. Furthermore, it is also impossible to separate out the skills of technology from those of science. These are closely related but not identical. Their difference relates to the different roles of the scientist and the technologist - enquiry and creation. This distinction must be inherent in teachers' systematic structure of the work in this field. (See Box 2.11)

Knowledge requiring recall

This embraces the general knowledge which must be at the fingertips of those learning through science and technology, and should be defined in context and after decisions have been made about other learning objectives.

Those engaging in the design decision-making process cannot afford to be continually "re-inventing the wheel". That is to say, there are innumerable pieces of knowledge and experience on which designers base decisions without continually reappraising their fundamental understanding of the principles involved. Some of this is knowledge conventionally thought of as scientific and if students are to operate within a technological context then they must learn how to access and to use such knowledge.

Box 2.12

This example lists a set of skills derived from a more overtly technological approach.

The skills of the technologist should be seen in the context of involvement in the technological processes and might be categorised as follows:

- skills of investigation, including the examination of problems and searches for relevant information
- skills of invention, including thinking of alternative solutions to problems
- skills of implementation, including selecting and planning the process of making things, the use of hand and machine tools, and the monitoring and controlling of details of the operations
- skills of evaluation, including assessment of the process, progress and product of the activity against objective criteria
- skills of communication

Attitudes

These define the contribution which science and technology make to the general education of the pupil. It is important that teachers should have a clear idea of the attitudes they wish to encourage in their students. (See Box 2.13)

Box 2.13

One school has listed the attitudes it seeks to promote and foster as follows:

Pupils should be:

- enthusiastic about science and technology and continue to be so irrespective of their career
- aware of and concerned for the social implications of science and technology
- aware of the relevance of scientific knowledge and processes to other curriculum areas and to their own daily life
- aware of the historical context of science and technology
- curious
- open-minded but with a healthy scepticism of accepted explanations
- accurate, honest and unbiased in their observations and communications

Summary

This chapter has sought to provide a bridge between the philosophical basis for science education as developed in Education through Science and the practical schemes which operate from day to day. The first step for any group of teachers is to develop a statement of intent, which encompasses a set of considered aims. In order to make these useful for teaching they have to be translated into learning objectives but here the story does not end. Learning objectives cannot stand in isolation. They are but a tool in the process of planning which leads to courses of study and decisions about methods and teaching styles.

CHAPTER 3

ORGANISING THE TEACHING OF SCIENCE

Introduction

The aims listed in Education through Science, and originally in Alternatives for Science Education, have caused hardly any adverse comment. Most school science courses nowadays would claim, for example, to provide scientific knowledge and skills, a scientific perspective on the world and society, and a broad, general introduction to science in the primary and early secondary years. Where Education through Science breaks new ground is in proposing radical new criteria for judging whether the courses are really likely to achieve these aims. Until recently too many schools and too many teachers within them have paid little more than lip service to the aims which were often written into syllabuses and prospectuses as afterthoughts. Busy practitioners, not surprisingly, tend to concentrate on methodology and the achievement of short-term objectives. They rarely question their effectiveness in achieving their broad aims. Examiners tend to fall into the same trap and the error is therefore perpetuated.

This chapter illustrates how some schools have approached the design of teaching and learning activities, the development of curriculum models which reflect the ethos of the school and the kinds of learning outcomes, and the development of personnel and resources through timetables. It is worthwhile at this point to reflect on the two major themes which underpin Association policy on the teaching of science in the school curriculum.

The first of these (summarised 'as science for all') is that science should no longer be based exclusively or primarily on the needs of an elite, but should aim to provide an appropriate education for all students, throughout their years of compulsory education, irrespective of ability. This raises the problem of devising strategies for coping with students of widely differing aptitude, interest and motivation while still providing a suitable foundation for the further, higher and continuing education of future experts.

The second theme is that science should contribute to the general education of all students, the ultimate aim of general education being to equip them to be autonomous learners and responsible future citizens. This contribution implies a broadening of the contexts of science education, to include societal issues, applications of scientific ideas and communication skills. Moreover, some of these aspects should not be confined to science lessons but should permeate the whole curriculum so that students come to appreciate the role that science has played in moulding our culture.

Learning strategies

Using objectives to plan learning experiences

The previous chapter discussed the purpose of aims and objectives and the ways in which a school or a science department might select them. This section explores ways in which aims and objectives can be converted into a strategy for action in the classroom. Objectives often state what teachers plan to do but do not always reflect the fact that teaching is also intended to bring about changes in the learner. They should specify what the students are to do and this cannot be achieved merely by listing topics or concepts. Even where objectives are stated in the terms of desired changes in the students, they

are often too generalised to be of much value. The first step in using objectives to organise the teaching of science is to express them in terms which both identify the kinds of behaviour to be developed in the student and the content area in which the behaviour is to operate. It is possible to establish curriculum content by using the strategies developed in Decisions in the Science Department, (Hull and Adams), Chapter 5. A convenient method of presentation is a two-dimensional chart with behavioural objectives along one axis and content objectives along the other. Such a chart can be used either to evaluate an existing course or to provide specifications to guide the development of a new one. Intersections of rows and columns in such a matrix represent learning experiences. (See Box 3.1)

Box 3.1

Learning experience matrix
prepared for a Nuffield Chemistry topic

Concept objectives

- C1 The idea of two types of charge
- C2 Charges can exert attractive and repulsive forces
- C3 The electron, current as electron flow
- C4 Conductors and insulators
- C5 Ions
- C6 Conduction of electricity by migration of ions
- C7 Ionic discharge at electrodes
- C8 Faraday's first law
- C9 Faraday's second law
- C10 The Faraday as the mole of electricity
- C11 The mechanism of electrolysis
- C12 Variable ionic charge
- C13 Ionic bonding
- C14 Explanation of discharge of hydrogen and oxygen from aqueous solution
- C15 Model of the atom (positive nucleus surrounded by discrete negative charges
- C16 Giant ionic structures and molecular structures
- C18 Periodic Table

Process objectives

- P1 Observing and recording
- P2 Presentation and analysis of data
- P3 Interpreting and making deductions
- P4 Sectional diagrams
- P5 Circuit diagrams
- P6 Detecting and identifying charge by repulsion
- P7 Fusing a salt
- P8 Setting up and testing a simple electrical circuit
- P9 Distinguishing conductors and insulators experimentally
- P10 Using a teat pipette
- P11 Weighing
- P12 Cleaning metal electrodes
- P13 Identifying lead
- P14 Identifying bromine
- P15 Collecting and identifying hydrogen
- P16 Identifying iodine
- P17 Identifying chlorine
- P18 Identifying copper
- P19 Measuring current, adjusting current in a circuit
- P20 Timing
- P21 Carrying out electrolysis of a fused salt
- P22 Carrying out electrolysis of an aqueous solution
- P23 Recognition of a typical ionic compound as such from its properties (conductivity, mp, etc)
- P24 Writing equations for electrode reactions
- P25 Deducing charge on an ion from electrolysis data
- P26 Calculating the quantity of electricity needed to discharge a mole of ions
- P27 Writing the formulae of ionic compounds
- P28 Reading
- P29 Writing
- P30 Talking
- P31 Listening
- P32 Using a data book
- P33 Simple arithmetical/algebraical skills

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18
P1	A	AB C	BD FH	DE	EF	EF G	FR PQ	K		PQ RS				PQ R				
P2			FH		F	F1	FR T	KT	T	T	T							
P3	AV	AB CV	BF IL	E	EF VW	EF GT	F1 KL	IK T	MT	MT	IN MP	TW	WI	PQ R	VW	I	I	WI
P4				E	E	E	K	K		S								
P5			DH	DE	E	EG	JK	JK		S								
P6	A	AB C	B															
P7			H	E	E	E												
P8			D	D			KP Q	K		PQ R				PQ R				
P9			D	D														
P10						G												
P11			H			T	KT	KT	T	T	T	T						
P12						T	KT	KT	T	T	T	T						
P13			F	F	F	F												
P14			F	F	F	F												
P15							PQ			PQ				PQ				
P16							Q			Q				Q				
P17							P			PS				PS				
P18										RS				R				
P19			H				JK	JK										
P20			H				K	K										
P21			H	E	E	E												
P22							KP Q	K		PQ RS				PQ R				
P23						I							I		I	I	I	
P24			IL			T	IL PQ	IO T	MO T	MQ T	IM MQ	T		PQ R				
P25			IL			T	IL T	IO T	MO T	MQ T	IM MQ	T						
P26			IL			T	IJ LT	IJ OT	O T	OT	IO T	T						
P27			IL		W		IL	IO	O	O	IO	W	W		W			W
P28					W	GI	KP Q	KO	O	O	OP QR	W	WI	PQ R	W	I	I	WI
P29			FH IL		FW	FI	FI KL	IK O	MO	O	IM OP	W	WI	PQ R	W	I	I	WI
P30	V	V	FI LV		FV W	FG I	FI JL	IJ	M	W	IM N	UW	WI		TW	I	I	UW I
P31	AV	AB CV	BF HI	E	EF VW	EF GI	FI JL	IJ	M	W	IM NS	UW	UW		TW	I	I	UW I
P32					W	I		O	MO	MQ Q	MW	UW	WI		W	I	I I	UW
P33			IL		W	T	IL T	IO T	MO T	MQ T	IM MQ	TW	W		W			W

From the multiplicity of options represented by the squares on the matrix, it is possible to select appropriate activities to ensure that students are provided with opportunities to achieve the stated objectives. Clearly it would be both undesirable and impractical to provide all the learning experiences represented by all the boxes in the matrix. This would lead to boredom and frustration. However it would seem sensible to provide activities represented by two or three boxes within each row and column. Different patterns will probably be appropriate for different students, depending on their ability, previous knowledge and special interests.

Learning experiences need to be organised into courses of study in such a way that there is continuity, sequence and integration. Continuity refers to the reiteration of learning experiences leading to the same objectives. For instance "to measure accurately and estimate" is dealt with repeatedly, not only in science courses but also in craft, the humanities and mathematics. Sequence goes beyond continuity because it emphasises the importance of having each successive experience built upon the previous one, thus developing breadth and depth. Integration requires the relating of learning experiences in such a way that students acquire a holistic view relevant to their daily life, rather than a set of isolated skills and concepts that they cannot apply to real, and perhaps novel, situations.

It is easy for the teacher to forget that continuity, sequence and integration have to be seen from the learners' viewpoint. Learners' and teachers' viewpoints are not necessarily the same. The teacher will already have established in his or her own mind a framework for what is to be learnt which may not be appropriate for students. A logical organisation which has meaning and significance for an expert may be viewed very differently by a learner who is unable to see the connections clearly.

There are times when science teachers, sometimes inadvertently, become learners along with their students and this implies that they will be teaching by discovery or enquiry methods rather than by instruction. Nevertheless, teachers must always accept responsibility as senior learners among other, more junior, learners. They will be expected to offer research skills, to have a philosophical understanding of the subject and from time to time to provide instructions and rationale. The strength of this kind of approach is that it enhances both the behavioural and content objectives by deepening understanding amongst the students and emphasising the process of learning.

Like every theory of curriculum planning, planning by objectives has been subject to criticism. For example some classroom events are too unpredictable to make detailed pre-planning useful. Pre-specification can constrain the teacher, lead to unimaginative teaching and may deny the learner any role in the planning. There will always be occasions when an unplanned and intuitive response by the teacher to a classroom situation may provide the most appropriate learning experience.

Managing the learning process

Teaching methods should be tailored to suit the objectives that a teacher has in mind at any particular time and this implies that there should be a variety of strategies employed. HMI have reported (Aspects of Secondary Education 8.9.1) that "More than anything else teaching methods affect the response of the pupils and determine whether they are interested, motivated and involved in the lesson in such a way as to be engaged in good learning, understanding and progressive development of skills."

It is important for teachers to adopt various teaching styles; they are sometimes listeners, sometimes partners, sometimes assessors; and they need to question, cajole, encourage and guide and to know when, when not and how to intervene.

Certainly no one teaching method is suitable for all situations and HMI (Primary Education in England 8.61) has drawn attention to the fact that "teachers need to become familiar with a range of teaching techniques, to understand the advantages and disadvantages that each has, and to choose what is best for their immediate purpose."

During the enquiry which followed up the HMI 11-16 working papers it was reported (Curriculum 11-16 Towards a Statement of Entitlement) that "The importance of methodology and classroom practices cannot be over-emphasised. If nothing happens in the classroom then curriculum ideas remain paper exercises - one of the main questions for teachers is "How do children learn and how can I as a teacher help them?" Often it came as a revelation to teachers that they were working on assumptions about children's learning which were over-simplistic.

Box 3.2

Questions

1. Does the work scheme mention a variety of teaching techniques and are these linked to the aims and objectives of the course? Is a good range of techniques actually used by each teacher?
2. What proportion of class time is spent by pupils in actually carrying out experimental work of any sort?
3. Is the balance between experimental work which is carried out by demonstration and that which is carried out by class practical suitable for the age and ability of the pupils?
4. Do the teaching techniques which are planned for this course allow sufficient time for pupils to be involved in discussion?
5. If it is necessary for the pupils to have an accurate written record of work done, is a range of methods of recording employed?
6. Are the activities which pupils carry out after an experiment varied to suit its purposes?
7. How effective is the use of homework time? Would it be worth structuring the programme of homework to make it a more integral part of the course?
8. Is there a planned and coordinated system for the use of audio-visual aids?
9. Is the variation in the abilities and preferences of individual teachers taken into account in the range of teaching techniques which are planned for the course or which are implicit in the course material?
10. If the same topics are taught to pupils from a wide range of ability, what direct guidance and help is given to teachers on how to vary the treatment accordingly?
11. Do the teaching methods used change sufficiently from year to year to prevent the staff becoming bored with teaching the course, but without putting excessive strain on them?
12. Is there an up-to-date list of any special skills or knowledge possessed by members of the department which might be useful in the course? Is general use made of this expertise?
13. Are some sections of work structured so that individuals can learn at their own pace?
14. Are pupils given a choice of activity at one or more points in the course?

From time to time it is useful for science departments to discuss class management, and teaching and learning strategies. Decisions in the Science Department (Hull and Adams, 1981) provides some starting points for this kind of discussion, which may usefully lead to a departmental policy for teaching. (See Box 3.2)

Assuming that the monitoring of student progress and the evaluation of courses is an intrinsic part of the teaching process, systems must be devised for assessment, recording of student progress, evaluation by individual teachers or by the departmental team as a whole, and regular modification and updating of courses in the light of such evaluation.

Towards autonomous learning

Traditionally, teaching and learning situations in schools have been teacher-centred. At all times a teacher has been in control, in authority, and has been seen to be so by students. There are, however, advantages to be gained, for part if not all of the time, by the teachers abandoning their dominant position. Learning decisions are then made by children working individually or interacting within groups of varying sizes. The teacher must still be available to act as a resource and as a facilitator.

There are various aids to individualised learning, but it is not reasonable to expect young people to switch without careful support and preparation from situations where they have been mainly passive, accepting the close guidelines provided by the teacher, and rarely having to make decisions, to an active role in which individual decision making becomes important. Some schools quite explicitly teach study skills with a view to developing autonomous learning. With this kind of preparation genuine project work becomes a possibility. (See Box 3.3).

Box 3.3

Project work in Mode 3 Physical Science

Guidance for teachers

The culmination of Mode 3 course is a major piece of project work in which the students select their own area of study, plan and carry out their own investigations and write a report. Few students, even those of quite low ability, have been found totally unable to benefit from this kind of opportunity.

In the early stages, students should be allowed an element of choice in selecting topics and encouraged to work independently within structured units of work in which a great deal of support is provided. However, they must be encouraged to progress to more and more autonomous situations until they become independent; choosing their topic, planning, selecting and carrying out background reading and research, executing and interpreting experimental work and writing a report.

It is advisable for departments to develop a bank of resources, fully indexed and available to students. It is then possible for the teacher to select from the available stock a number of units from which students have a choice. The units selected depend upon the age, ability and interests of the students and not least upon the basic scientific knowledge that they have already acquired. Some guidance on choice may be provided for individuals and each student's programme must be managed so that the content objectives and behavioural objectives previously decided can be achieved. This implies very careful record keeping. 'Introduction and Assignment Sheets' may be provided to aid students in making their choice and to guide them through the unit. Each student or group studying a particular unit can be provided with the same apparatus but instructions and work sheets are selected to suit individual needs. Sometimes teachers using this technique will find that they need to write material for particular students but will file such material for possible future use.

In this way the level of difficulty and open-endedness can be varied to suit the ability and level of development of individuals, the aim being to wean them gradually away from teacher dependence over a series of such units, so that towards the end of the course students can tackle project work with the maximum confidence and independence. (See Box 3.4).

ASE Study Series 'Resource-based Learning in Science' provides a useful source of ideas and information to assist with individual and small group learning.

Box 3.4

Possible special study titles

Photography
Metals and alloys
Air transport
Building materials and modern plastics
Rockets and space travel
The solar system
The weather
How are rocks formed?
The science of cooking
Electricity in the home
Keeping healthy
The eye and the camera
Colonisation, disease, pest and weed control
* Animal husbandry
* Crop rotation
Electronics
\+ Making and testing simple machines
\+ Bridges
++ Atoms and the periodic table
++ Finding out how atoms are arranged in substances
++ Electrolysis
The senses

* These units are suitable for schools which have facilities for rural studies. They differ from most other special studies in that experimental work would probably have to continue at intervals over an extended period.

\+ These units would be facilitated by the availability of workshop facilities and appropriate specialist expertise of staff.

++ These units illustrate chemical topics for the more able academic students, providing a basis for A-level work. Suitable schemes could also be devised in biology and physics.

Teachers working together

Flexible and individualised work patterns can, unless systematised, provide intolerable workloads for individual teachers. Carefully organised and catalogued resource banks are necessary with all the teachers expected to use and contribute to them. It is important that teachers share this work and support each other. This need not necessarily imply team teaching, in which more than one teacher works in the classroom, although this has been found a useful method in some schools. Design and architecture of the buildings can help or hinder this technique. One rather less ambitious procedure which has been found valuable in some science departments has been to have an extra teacher, a floater, to support a team of perhaps four or five teachers working separately with parallel classes. The floater can then give help to

individuals or groups as required, either at the request of the class teacher or on his or her own initiative. This will not necessarily mean that the less able are always being provided with extra support. It can be equally useful in stretching and interesting very able or highly motivated students.

Even if a department uses no team teaching at all, it is considered essential that preparation of teaching schemes, resource material, assessment and evaluation should be carried out on a team basis. It is a particularly useful method of employing the expertise of specialist teachers effectively in integrated courses. Specialists not only have a role to play in preparing material within their area of interest but should act as consultants for both colleagues and students on a formal or informal basis.

Box 3.5

Assessment circuses

Circuses usually consist of about five experiments done over a period of five lessons. Pupils are expected to work individually and independently. Each experiment is a practical problem (e.g. finding the resistance of a piece of wire, comparing the rates of reaction under different conditions, purifying a substance, comparing the carbon dioxide content of inhaled and exhaled air). Precise and detailed instructions are given - the design and planning of experiments is not being tested. Students are allowed a limited time in which to complete their practical work, but are allowed to write up and interpret their results during homework or private study. Experiments are related to work done in earlier core science units and normally the apparatus used is familiar. Results can be presented in a variety of forms and it is stressed that interpretation of them is important. Each experiment is complete in itself. Absence presents no serious problems. Although this work was originally developed purely for assessment purposes, the students greeted the experience with great enthusiasm and it has been found to be of value in the development of practical and interpreted skills.

Practical work

Practical work carried out by students is an essential ingredient in any school science course. In the Secondary Survey (Aspects of Education in England and Wales) HMI expressed some dissatisfaction with the quality of the experimental work that children do in some schools:

> "where good teaching is observed and group practical work is an important part of the normal teaching method, the pupils are better able to gain experience of the processes of science, including the skills of observation, experimentation and prediction. Unfortunately, few opportunities are provided for pupils to conduct challenging experimental investigations. It goes without saying that, unless children or students are experimenting or testing for themselves on a regular basis, they are unlikely to be learning through science."

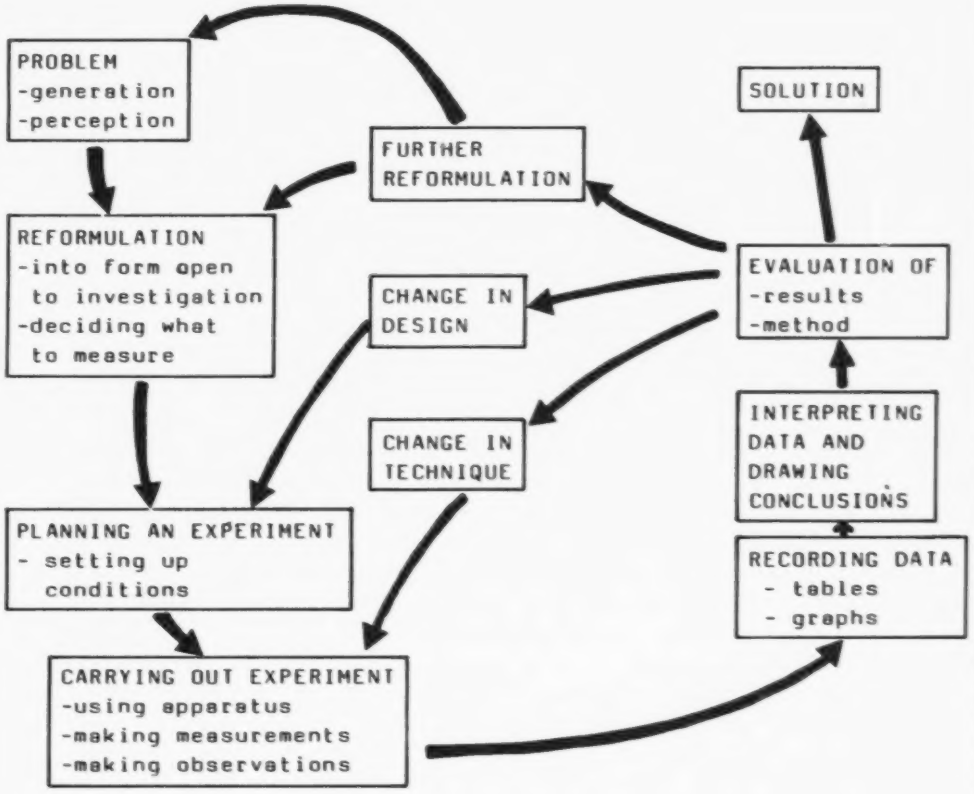
The assessment of practical work has for many years been a cause for concern, and external practical examinations have many drawbacks. Continuously assessed practical work has attractions, but it can be time consuming and is very difficult to moderate. Some schools have developed experimental circuses for assessment purposes. (See Box 3.5)

The Assessment of Performance Unit (APU) is using practical tests for assessing the use of apparatus and measuring instruments, and in the use of interpretation and observation. Furthermore, the teams have devised methods for assessing students' performances in the carrying out of open-ended practical investigations (APU Science Reports for Teachers 1 - 7).

To carry out the investigation of a problem satisfactorily, students need to progress through a chain of different processes and, for the best students at least, the investigative process is an interactive one. The first stage is the generation and perception of the problem followed by reformulation into a form open to investigation and a decision about what to measure. The experiment then has to be planned and the appropriate conditions set up. Next comes the carrying out of the experiment, using apparatus, making measurements and observations. The data has to be recorded in some suitable form and then interpreted and appropriate conclusions drawn. After that the student should evaluate both the method used and the results. This may or may not lead to an acceptable solution in which case changes in the investigation may have to be made before it is repeated. (See Box 3.6).

Box 3.6

Links in a Problem Solving Chain



Source: The Assessment of Performance Unit
Science in Schools. Age 13

The APU monitoring of science would be very difficult to recreate in school for every child or student. However it provides a challenge, and it has already indicated a great deal about the design of science teaching and learning.

Curriculum Models

Learning experiences have to be built into a framework which can be called a curriculum model. There are a number of models available, including the following:

- linear courses
- modular courses
- thematic/issue-based courses
- spiral courses
- stratified courses

Linear courses

Traditionally such courses are described in syllabuses in content terms. The whole class works through the menu of topics in a pre-determined way, perhaps with additional or alternative work for students with special needs. (See Box 3.7)

Box 3.7

Physical and chemical change;
elements, compounds and mixtures
States of matter
Atomic theory
Atomic structure
Periodicity
Chemical bonding and structure
Symbols and formulae
Chemical reactions
Chemical equations
Air, combustion, rusting and photosynthesis
Water and solution
Acids, bases and salts
Metals: extraction and uses
Metals: general properties
Hydrogen
Oxygen and its compounds
Sulphur
Compounds of sulphur
The halogens
Compounds of the halogen
Carbon and its compounds
Organic chemistry
Nitrogen and its compounds
Oxidation and reduction
Rate of reaction
Energy changes in chemical reactions
Equilibrium
Relative atomic mass
Calculations involving masses
Volumetric analysis
Calculations involving solutions
Electrolysis
Revision

There is a danger that such a course might leave the learning of skills and processes to chance. To avoid this, the teacher could have a list of behavioural objectives which is used as part of a profile. The teacher then notes when a student has mastered a particular objective. Such a method raises the issue of assessment procedures. An alternative procedure would be to write the syllabus in terms of learning experiences decided by use of the two-dimensional matrix already described.

It is essential that the special needs of individuals are catered for. Extension work can be provided for the more able but it is important that this should not simply be 'more of the same'. Extension work must be demanding, different from what has gone before and capable of stretching the students for whom it is designed. In some cases it may be more appropriate to provide, instead of extension work, alternative or differentiated work for very able students and certainly for the less able. The model does not necessarily require that all students should be taught together and indeed this becomes more and more difficult as the ability range widens with increasing age of students. The essential feature is to draw up aims, objectives, core content, and a list of appropriate learning experiences for all students. This is already quite commonly done up to the third year of secondary education.

Modular courses

These should provide greater flexibility than the linear model. Modules can be designed, written, edited, evaluated and modified in order to provide suitable learning experiences. Most departments would wish to include some common content material, considered essential basic scientific knowledge, for all students. This implies that all students complete the modules in the same order. Another approach would be to provide a set of parallel modules covering each essential content area, perhaps graded by ability levels. Students would negotiate with their teachers their choice of additional modules. As a student progresses the teacher can plan the work so as to increase the demands and to provide remedial support where necessary. As students develop confidence and the ability to plan their work progressively, more open-ended modules can be provided leading ultimately to genuine project work. In this model much of the work would be individualised but opportunities for group work and discussion can be built in to the basic modules. Each module should include assessment material although there may also be a place for assessment modules, particularly for practical skills.

An example of a commercially produced modular package which is very popular is 'Science at Work'. It is not appropriate for the whole ability range. (See Box 3.8)

Box 3.8

Science at Work

A series of 18 science units for 14-16 year old, less able pupils. Each unit consists of a pupils' book and a teachers' guide. Each provides a half term's course of study. The units are self-contained, can be taken in any order and each increases in difficulty as the student progresses through it. The course has general objectives and then each unit has more specific objectives in terms of the skills and knowledge that students will experience. The teachers' guide contains masters of students' response sheets, assessment tests and apparatus requirements. The course can be used for Mode III CSE.

Units

Fibres & Fabrics	Food and Microbes	Electronics
Domestic Electricity	Forensic Science	Dyes & Dyeing
Photography	Earth Science	Gears & Gearing
Science of the Motor Car	Cosmetics	Plant Science
Body Maintenance	Energy	Pollution
Flight	Building Science	You & Your Mind

Thematic/issue-based courses

These can be very flexible and open-ended, requiring thought and imagination on the part of each teacher and the departmental team as a whole. National and local issues can be used as vehicles for the teaching as can the special interests of students. This provides excellent opportunities to introduce and follow up social, political, economic and cultural issues. The method also places a premium on the development of science processes. There needs to be an extensive, easily accessible and constantly updated resource centre as back-up. It will include some self-contained teaching units but also additional background information. Class and group cooperative work and discussion techniques are well suited to this approach. Because of the open-ended nature of this kind of model, the management and assessment of learning experiences are crucial. The Schools Council Integrated Science Project is one example of a secondary school thematic model. (See Box 3.9).

Box 3.9

SCISP Patterns

Building Blocks

1. Recognising change
2. Changes in behaviour
3. Changes in acidity
4. Changes in motion 1
5. Changes in the Earth
6. Changes in organisms
7. Changes in motion 2
8. Changes in atoms
9. Changes in molecules
10. Changes in populations and communities
11. Stability
12. Changes in the environment
13. Changes in society

Energy

1. Transferring energy
2. Energy and particle interactions
3. Energy and electricity
4. Sources of energy
5. Using energy efficiently

Interactions and Building Blocks

1. Competition and predation
2. Particle interactions
3. Electrical interactions
4. Earth, water and organism interactions
5. Motion
6. Classifying building blocks
7. Distribution of building blocks

Interactions and change

1. Recognising change
2. Changes in behaviour
3. Changes in acidity
4. Changes in motion 1
5. Changes in the Earth
6. Changes in organisms
7. Changes in motion 2
8. Changes in atoms
9. Changes in molecules
10. Changes in populations and communities
11. Stability
12. Changes in the environment
13. Changes in society

Appendix: Technology and patterns

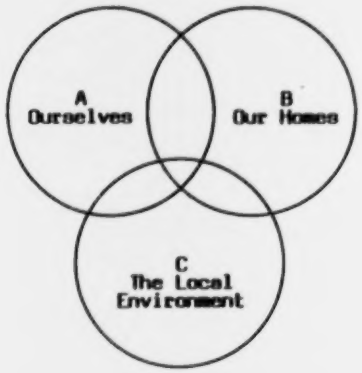
Students in primary and junior schools can also have their science learning structured in a thematic way. (See Box 3.10).

Science in a social context has become increasingly popular in courses designed for sixth formers. However, Education through Science suggests that science should be seen in its cultural and sociological context during the earlier years of schooling. Another working party of the Association has recently published a paper (Rethinking Science? - Teaching Science in its Social Context) and this largely pre-empts any statement that this working party would wish to make.

Box 3.10

A Junior School Thematic Model

There are three themes:



C. <u>The Local Environment</u> (an example of one of the themes)

- simple plans, introduction of scale, and further use of coordinates.
- services.
- spatial and numerical aspects of the surroundings.
- soil, weather, plants.
- buildings, style, comparisons, shape, height, uses, etc.
- types of movement.
- uses of the land : shopping, leisure etc.
- communications, linked to maths etc.
- industry: processes, tests involved in production. May be associated with creative work.
- in the garden : plantings, germination, growing plants, the harvest, types of plant, sizes, shapes, etc.
- random studies of various habitats : plant and animal counts, comparisons. Animal safari, etc.
- the weather, : observation, rainfall, hours of sunlight, wind strength and direction, changes in temperature, cloud form, relationship between various conditions. Protection from the weather. Rainbow, spectrum - use of prisms.
- water : to our homes, rivers (use of sand trays for development of valley forms), waste, sewerage, etc.
- landscape : development of settlements (reasons, etc).

General procedure of study should involve appropriate vocabulary development during discussion, forms of comparison, testing for variables, observing at depth and the use of a wide range of recording techniques.

From the initial look at the local environment, studies may be extended to introduce work on topics such as:

- food - types, growth, availability, food chains, etc.
- structure and support - buildings, bridges, etc.

Through the use of appropriate resources, e.g. maths equipment, timing equipment, tapes, rulers, etc., pupils should gain a realisation of their capabilities, show ability in evaluating facts, and present recordings, views, etc., in a pleasing and acceptable manner.

It is very hard to integrate any historical or cultural perspectives on science into traditionally designed science courses. In one school, the curriculum planning team felt that the issues raised by modern science were so important that a whole course is now devoted to this subject. Other schools or science departments might wish to integrate this work into their main science courses or to include special issue-based modules in their courses. (See Box 3.11).

Box 3.11

One schools issue-based approach

A typical class discussion unit begins with a formal presentation, perhaps using film or slides. Pupil involvement includes class or group discussion and reading. Sociological or environmental surveys must be conducted by pupils locally and then analysed, or previously prepared data can be used. Laboratory practical work is incorporated wherever possible, preferably suggested by the pupils themselves.

This type of work might profitably be conducted in cooperation with the Social Studies department. Although it would involve individual activities, it would be essentially a corporative exercise by the whole class. Pupils produce one or perhaps a short series of written pieces of work or some other form of presentation, such as posters. This work can be set for homework and cooperation with the English or Art and Design departments is valuable.

These units are numerous but each one is quite short. There are 24 class discussion units, each one lasting approximately 8 periods (2 weeks).

This plan has been developed into an issue based approach involving practical work (See Box 3.13).

There is no shortage of topics for such thematic or issue-based approaches. (See Box 3.12)

Box 3.12

Examples of suitable topics for a thematic or issue-based course

- various historical topics such as the discovery and development of electricity, burning and the discovery of oxygen, plastics and man-made fibres
- human reproduction and sex education, including moral and social issues relating to topics such as birth control and venereal diseases
- the world food problem, including issues such as pest and weed control, intensive agricultural methods, battery farming, alternative food sources, etc.
- the management of water resources
- socioeconomic studies of local and national industries
- health and hygiene, including an introduction to microbiological techniques
- space exploration
- communications systems, computers and microprocessors

Box 3.13

One example of an issue-based unit

Fuels

Before the unit starts, pupils fill in a questionnaire about the use of various fuels in their own home and the measures taken to conserve heat, etc. (A suitable proforma is given in LAMP Topic Brief Fuels.) The results are collated in class and then discussed. It is sometimes interesting to compare the survey with those for previous years, noting any changes and discussing the reasons for them. There follows a demonstration and discussion session exploring the questions, "What is a fuel?" and "What are the uses of fuels?". During the course of this lesson an oxygen/hydrogen mixture should be ignited inside an unrestrained plastic container to show that fuels can be used to provide kinetic as well as heat energy. To start a fire you need a fuel, oxygen and normally a source of heat, but spontaneous ignition should be mentioned and can be demonstrated by pouring a few drops of a solution of phosphorus in carbon disulphide onto a dry filter paper. Safety precautions are then discussed and the correct way of extinguishing a petrol fire demonstrated.

A variety of films are available showing how fossil fuels were formed and how they are won. Examples are the British Gas film 'I'm glad you asked that question' and the film strip from the BP collection, 'North Sea Adventure'. These audiovisual aids should be supported by a poster display in the teaching base. This can be followed up by written work, set as homework for the pupils.

Pupils are then asked to decide which are the desirable properties of fuels. A list is given in Nuffield Secondary Science, Volume 7, but it is best to ask pupils to produce their own list, either individually or in class discussion. A variety of fuels are made available for testing, including unconventional ones such as paper or sugar. Pupils observe these fuels burning and try to make a decision on which is the best fuel by checking against their prepared list. Inadequacies in this simple procedure soon become apparent, particularly the questions of cost and pollution, but there is normally a consensus of opinion that "natural gas is best". Discussion might then centre on the historical development in this country from our traditional dependence on wood as a fuel, to charcoal, coal and finally oil and natural gas. Nuclear energy might be discussed, as well as alternative sources of energy.

Further practical work follows, including a closer look at the effective costs of various fuels. An experiment is described in Nuffield Secondary Science to compare the cost of three fuels (methylated spirit, butane gas and 'Meta' fuel) used in camp cooking but, again, pupils should be encouraged to devise their own experiments once they are aware of the basic idea that a simple comparison of cost/weight ratio is not sufficient.

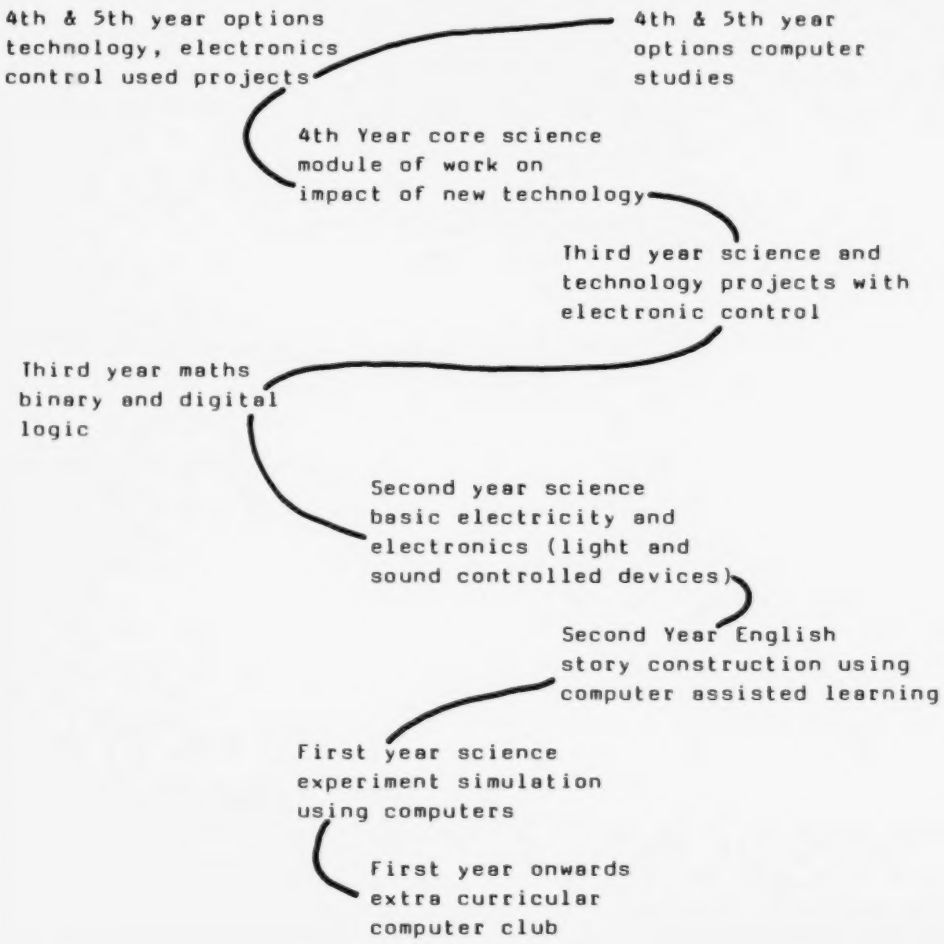
This is probably sufficient work for the time allocation suggested. The question of pollution caused by fuels could be examined in a later class discussion unit. This should include an understanding of the hazards of sulphur dioxide, carbon monoxide (caused by incomplete combustion) and lead from petrol engine emission.

Spiral courses

These aim to provide a sequence for teaching within a topic so that the pupils move from the basic and fundamental skills and processes to the more complex ones and have sufficient mastery of individual skills and processes to be able to use them in conjunction with each other. The programme must be a spiral so that after each skill is taught it is reinforced and elaborated, ideally not only in science lessons, but throughout the whole of the curriculum. (See Box 3.14)

Box 3.14

A Curriculum Spiral to develop Information Technology Skill


4th & 5th year options technology, electronics control used projects
4th & 5th year options computer studies
4th Year core science module of work on impact of new technology
Third year science and technology projects with electronic control
Third year maths binary and digital logic
Second year science basic electricity and electronics (light and sound controlled devices)
Second Year English story construction using computer assisted learning
First year science experiment simulation using computers
First year onwards extra curricular computer club

Spiral programmes are particularly appropriate for the teaching of study skills. Teachers can include reading tasks such as sequencing, cloze procedures, comprehension and prediction exercises etc., so as to increase students' ability to read actively. In the early stages, writing can be mainly personal and lively with the structured move to more formal transactional writing later in the course. This sort of approach is particularly valuable if science is taught in mixed ability groups, because to be successful students must have the skills needed to become independent learners. These skills include reading, writing, talking, listening, study skills, ability to plan projects and investigations, time management, essay writing, analysing problems, collating and communicating information (See Bulman, Teaching Language and Study Skills in Science).

Stratified courses

This is similar to the spiral model in that students return at intervals to earlier work, looking at it in greater depth as their understanding of science matures. Content and skills are reinforced and elaborated. The stratified model may be structured in terms of content rather than process. It can be used to provide specialist teaching in separate science subjects without the necessity for separate timetable slots. Different subjects are taught consecutively rather than concurrently by using a team of specialist science teachers who rotate from class to class. (See Box 3.15).

Box 3.15

A Stratified Science Curriculum

In order to bring together language, mathematics, aesthetic activity, science and technology, a group of staff planned a programme of work for a team which culminated in a dramatic production involving 300 children.

The story line follows the adventures of the daughter of a scientist on the dying planet, Elsar. Her father has built a space-ship to search for a solution to their problems. In the opening scenes, she clearly forgets Health and Safety rules in the laboratory and accidently launches the space ship on its pre-programmed journey. The first visit is to Earth where the onboard computer with a fine turn of wit describes the environmental conditions necessary for life. Visits to other planets introduce hidden messages about unscrupulous leaders, how failure to care for the dental health of pet monsters can make everyone unhappy and how we too easily brand people as failures. After collecting a key letter from each planet, the space-ship returns to Elsar where the letters are shuffled to provide the answer to its problems - WATER!!

Throughout, ideas are introduced about the conservation of resources and the potential of high technology through song, dance and dialogue. However, the production was the culmination of a term's work in which pupils experimented with electronic sounds and light effects, the visual effect of properties and make-up, electronic feedback, and the concept of mass and energy change.

An important ingredient in such a stratified approach is that the teachers work as a team to plan experiences and introduce ideas in a range of different contexts.

Timetable frameworks

Curriculum models have to be considered from the viewpoint of both the time-tabler and the curriculum planner and the decisions arrived at have to be compatible. In the following discussion it is assumed that the timetabler has to work within the constraints of the overall time available and the choices available are listed below:

- integrated science
- a core of integrated science with the option of further science
- a common core and alternative extension courses
- core science in the early years then a choice of options
- a two subject model
- a coordinated three-subject model
- an inter-disciplinary model

Integrated Science

These courses have a respectable pedigree. SCISP is a well known scheme which integrates different subject areas. Nuffield Science 13-16 is a direct offspring of the Nuffield Secondary Science project and SCISP. Students taking these courses in the fourth and fifth year will spend 20% of curriculum time in science lessons.

A core of integrated science with the option of further science

The further science may be a common course run concurrently with the core or may require a choice from a set of alternative options (e.g. further biology, further chemistry, further physics). One school that is very careful to encourage all students to develop a general awareness, while allowing those who wish to do so to specialise, provides a common course in the first three years, largely based on Insight to Science. In the fourth and fifth years all students follow a course that is primarily concerned with social issues although there is some laboratory work. In these two years there is no further compulsory science but students may choose up to three science subjects within a traditional options pattern. (See Box 3.16).

Box 3.16

YEAR	CORE	OPTIONS				
1	Insight to Science					
2	Insight to Science					
3	Insight to Science					
4	STAS*	P	C	B	Electronics	Human Biol.
5	STAS*	P	C	B	Electronics	Human Biol.

*Science, technology & society

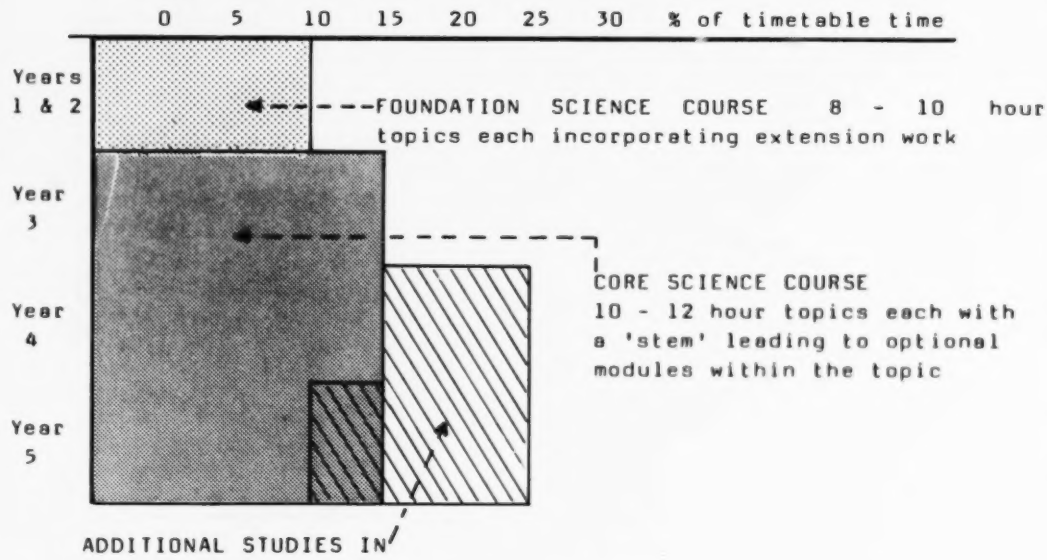
Five option blocks
Students may choose from 0 to 3 sciences

A common core and alternative extension courses

The extension courses may cover different content areas and/or be designed for different ability ranges. In some schools students select their own extension work; in others the choice is made by the staff, perhaps in consultation with students and their parents. A foundation course is provided in the first two years, followed by a core course with alternative additional studies. (See Box 3.17)

Box 3.17

Course model - core plus additional studies


0 5 10 15 20 25 30 % of timetable time
Years 1 & 2
FOUNDATION SCIENCE COURSE 8 - 10 hour topics each incorporating extension work
Year 3
Year 4
Year 5
CORE SCIENCE COURSE
10 - 12 hour topics each with a 'stem' leading to optional modules within the topic
ADDITIONAL STUDIES IN SCIENCE COURSE
same topic structure as in Core Science

All students follow Foundation and Core courses

Some students choose to follow the additional studies course in science as well as the Core course in Years 4/5

All courses are:
- non-differentiated in science
- followed by unstreamed groups
- taught by teams of teachers in double labs.

FOUNDATION SCIENCE uses campus-based resources often in the form of printed booklets. Self-pacing is encouraged and extension work is available.

CORE SCIENCE AND ADDITIONAL STUDIES IN SCIENCE use the Nuffield 13-16 materials as a starting point from which to select and deviate, using additional commercially produced and campus-based resources The topic model is an idealised one and varies in emphasis between different topics, tending to be less complex in Year 3.

The minimum core leads to O-level or CSE in Combined Science while those also doing the additional studies take the double subject, Physical Science and Environmental Science.

Core science in the early years then a choice of options

A pattern that is becoming more popular in schools is a common science course in the first three years, followed by a range of science options from which students must choose at least one. The choice of option may be left to the student, usually after guidance and consultation with the parents. Subjects available may include the traditional ones as well as alternative subjects such as electronics and human biology. It is hard to conceive of many common

principles and processes which such a variety of subjects could provide and it is extremely unlikely that the pursuit of just one science within such a structure could provide the sort of balance that both ASE and HMI recommend. The latter, for example, make it quite clear that both physical and biological science should be continued to 16+.

A two subject model

The two subjects most commonly used to exemplify this model are physical science and biological science although there are other combinations which can provide the appropriate breadth of study. It would require some teachers to widen their teaching base but might not appear as threatening as a fully integrated model and would continue to provide a reasonable weekly contact time between teacher and student.

Some schools have made physics compulsory for all as a somewhat crude device to prevent the traditional defection of girls from physical science to biology. This type of 'end on' core + options model could be rationalised by offering a very limited range of options. These might be:

- A. Physical science or engineering science
- B. Biological science or environmental science
- C. Integrated science

Students could study either A and B or C, thus provided individual courses are well planned, achieving a balanced overall course in science.

A coordinated three subject model

There are many individuals and groups who argue for the teaching of all three separate sciences to all students up to 16. The Royal Society urges this approach very persuasively while recognising that, because of the proper demands of other subject areas, there would need to be a reduction in the amount of time spent on each subject (compared with the present situation) of about 25%. This, they claim, could be achieved partly by reducing the total content and so avoiding the overlap which undoubtedly often occurs at present.

Coordination implies detailed consultation between the subject specialists and joint planning of the overall course. Teaching topics more than once can be avoided. Alternatively, they could be planned in such a way as to reinforce topics covered earlier in other subjects. Certainly it would become much simpler to coordinate work if all three sciences became compulsory. However, if every student had three different science teachers for a reduced contact time (perhaps little more than one and a half hours per week) there would be difficulties in teachers and students getting to know each other. Efficient management of courses as well as successful group dynamics demands at least two meetings per week for a substantial period of time. There is also the very real danger that the apparent breadth of study provided by such a curricular structure could be illusory, unless special efforts are made to ensure that the less traditional study areas, such as earth science and the human sciences, are covered. Coordination is often left to chance.

Moreover such proposals reveal a perception of syllabuses primarily in terms of factual content rather than process. Courses should be planned as a series of learning experiences devised with both content and behavourial objectives in mind.

An interdisciplinary model

There have also been experiments with totally interdisciplinary models, frameworks in which not only the traditional boundaries between the sciences disappear but science studies are integrated wholly or partly with other subject areas. There are obvious dangers of such an approach and it would

require highly skilled and dedicated teachers to operate it. One example of such an interdisciplinary model might focus on the symbiotic relationship between science and technology. (See Box 3.18).

Box 3.18

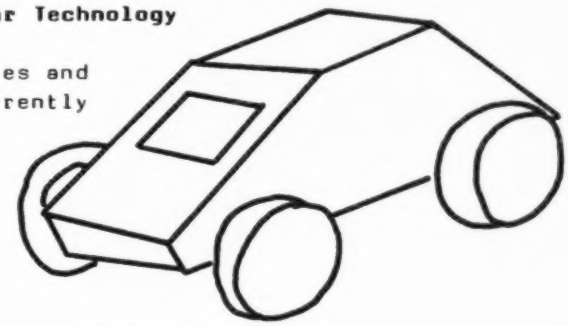
An example of completely linked work

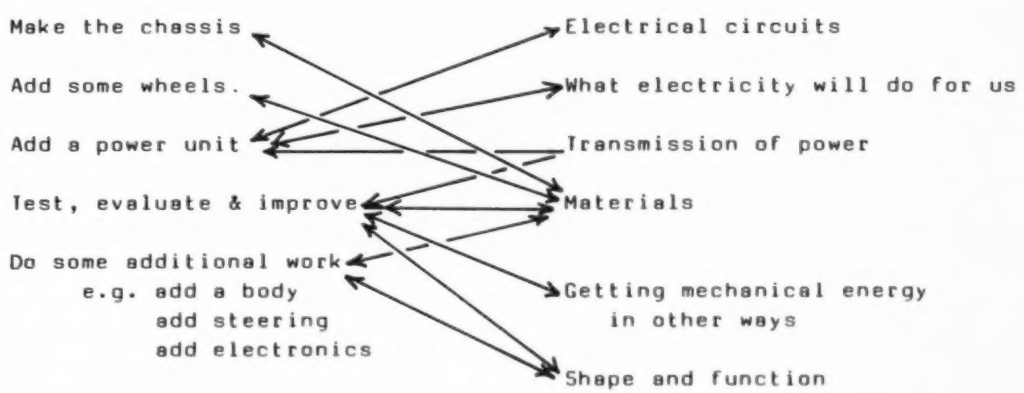
In this school the CDT and the science departments work together on several units of work. This one is an example taken from the second year in the secondary school.

In this unit the pupils have to design and build a self propelled car. The students work on two parallel linked strands which run concurrently in technical studies and science lessons.

2nd Year Technology

Lessons in the technical studies and science departments run concurrently between New Year and Easter.





Education through Science focuses on the relationship between technology and science. They are so closely related in the real world that it is hard to discuss them separately and yet in some schools there is little or no communication between science departments and CDT departments, nor any overlapping of the teaching of concepts and skills or the sharing of facilities. One school has adopted a very radical approach to this problem and has appointed a coordinator for science and technological development. The first task taken on by the coordinator was to draw up a matrix to identify what should be taught in relation to both areas and what was being taught at the moment.

In another school, students in the second year study a unit on the impact of industry. (See Box 3.19)

Box 3.19

Home Base Curriculum

This is an integrated course (of different modules) taught by an interdisciplinary team of teachers. The teachers have specialisms in mathematics, English and the humanities as well as science and technology. This scheme is discussed in more detail in Chapter 4. This is quite a different approach to science and technology from the one described above. Science is placed in a historical and cultural context, the aim being to integrate important content areas drawn from history, science, geography and other subjects. Key ideas are chosen to identify a series of central events, turning points or otherwise important moments, using a structure for investigation derived from real human situations properly observed. Students can see a number of possible outcomes and freely speculate about the relationship of different elements in a crisis or event. This type of approach enables students to observe and to think about the technological process, although perhaps not actually to participate in it. It may be that both the approaches described are necessary. Whatever approach a school decides to adopt in teaching technology, it seems clear that an integrated system of some kind is required involving a number of different specialisms and subject departments.

Summary

Two major themes in Education through Science are:

- science for all
- general education through science

Both these themes are difficult to implement in practice - this chapter illustrates how some schools have attempted to overcome the problems.

The chapter is arranged so that the first focus is upon teaching styles and learning strategies : planning and managing the learning process; autonomous learning; teacher deployment and cooperation and practical work.

Once teachers have discussed this the next focus for organising the curriculum should be planning the types of course in which the learning strategies take their place. These include:

- linear courses
- thematic/issue based courses
- spiral programmes
- stratified courses

When teachers have discussed the type of course appropriate for the learning strategies, the third part of the chapter explores various ways in which curriculum models can be timetabled. Different timetable frameworks include:

- integrated science throughout
- core science and further science options
- core science and alternative extension courses
- core science up to 14 with choice of sciences in 4-5 (one science minimum)
- two sciences (physical and biological sciences) for all
- coordinated three subjects for all
- interdisciplinary courses (science and other subjects such as technology)

CHAPTER 4

PROGRESSION, CONTINUITY AND COMMUNITY

Introduction

A worrying aspect of secondary school science in the United Kingdom is its tendency to be isolated within the curriculum, a problem focused upon in Education through Science and already mentioned in this report. Moreover, constructive liaison between secondary school teachers and their colleagues teaching science to younger children seems to be rare, even where effective primary science programmes do exist. Finally there is concern about the relation between science teaching and the needs and potential support of the local community, especially industry and commerce. There are, of course, many exceptions to these broad generalisations and the remainder of this chapter is devoted to the discussion of existing good practice.

Early Experiences

Education through Science recommends that science should be an integral part of the primary school curriculum and expresses concern that too often this is not the case. This situation does appear to be improving, as more and more interest is taken in the teaching of science in the primary school and some very good science programmes have been devised. There is still a great deal of room for improvement and for the provision of adequate opportunities for all pupils in the age range 5-16. Students should experience something of the creative and imaginative excitement that can be generated through exposure to scientific ideas and experiments. There are many reasons why this situation is not universal and why the pace of change is slow. Education through Science lists the following constraints:

- lack of suitably trained teachers
- lack of properly planned and continuing in-service training for those who wish to improve their confidence and expertise
- lack of adequate support facilities and technical assistance
- shortage of time for course planning (Very few primary science teachers, for example, have any time during the working day when they are not teaching.)

None of these problems can be alleviated by any short term measures. However, the Association has taken steps through its publications and committees to provide studies and resources for teaching primary science and through its interest in the quality of INSET by the validation of short courses for teachers.

Many primary schools have taken up the challenge and have developed science courses which are an integral part of the whole school curriculum (see Chapter 3). Some primary schools have a teacher who acts as the science leader but they may not have any formal training in science beyond their own schooling and they make up for this lack with great enthusiasm and interest in science.

A wealth of published materials for the classroom have been produced and there have been a large number of courses for primary school teachers at both national and local level, but still more needs to be done and there is a special need for continuing support, term by term, for those teachers who have taken part in initial courses.

Promoting Continuity

Some form of progression, continuity of experience and expectation, needs to be established from the reception class at the beginning of a child's school life through to further education at 16+. In particular, teachers in secondary schools need to be much better informed about the increased scientific experience of children leaving primary schools which do have effective science programmes, and to respond to this experience. They should rethink and adapt the courses for the first years in the secondary school in the light of what is happening in earlier years. (See Box 4.1)

Box 4.1

The Measurement Topic

Many secondary schools start the science course with a unit of work on measurement and laboratory skills, developed in a systematic way, starting with length and progressing through to volume. One school found that the children became too reliant on the worksheets and their expectations for science became blunted. Furthermore diagnostic tests indicated that the work was insufficiently flexible to meet the needs of range of ability. This was reinforced in discussion with science/mathematics post holders in the primary schools.

The secondary teachers explored the possibilities of using a problem solving approach. As a result the introduction to secondary science is through a model car project. The students, in teams, are required to design and make from card and wood a vehicle which will run down a slope carrying a specified mass of dry sand. Only wet sand is provided, along with a variety of resources and normal science equipment.

The students are assessed on their personal written record, oral work, their attitudes towards team work and their ability to assess, in groups, their design and those of others.

The establishment of professional links between first, middle and upper phases of education, in which teachers working together at local level to provide mutual support, enables the barriers which inhibit the development of coherent science curricula throughout the age range to be overcome. This kind of liaison has developed in some areas of the country and the following is a description of one such link scheme. (See Box 4.2)

Box 4.2

A group of local science leaders and other teachers meet regularly, visiting each school in turn, the aim being to provide a forum for discussion. There is no intention to formulate a prescription of course content and the secondary school specialists make it quite clear that they have no intention of handing down wisdom on tablets of stone - all members of the group are equal partners in the curriculum development process. The theme for each meeting is decided in advance; the context may be course content or skills. The representatives of each school explore the theme and illustrate it by pupils' work. This acts as a focus for discussion on the aims of the course in each school and/or the spreading of ideas. During discussion, content maps may be drawn up and aspects of continuity considered between the different age levels.

The next example describes how a linked group of schools approached the coordination of health education. (See Box 4.3)

Box 4.3

Coordination of Health Education

All schools collected the printed materials that they used and information about audio visual resources and the agencies that they used for their courses. The community school nurse also attended. Through discussion it was found that there was a wide range of breadth and depth in the courses followed and that material used in the secondary school duplicated work done in some of the primary schools. All schools found it beneficial to exchange information about their approach to health education. The link produced agreement on the broad areas that would be covered in the primary schools and the first two years of the secondary school. Schools also developed a coherent policy on audio visual resources and outside speakers they would use, and decided upon teaching and learning appropriate to each school. This initial project strengthened the original tentative contacts and acted as a foundation for further liaison.

Meetings between teachers from different schools undoubtedly improve relationships and members of groups get to know such mundane but important things as times during the school day when teachers can best be contacted. This liaison may lead to the coordination of resources, equipment and materials between the schools in the link. Teacher exchange and the sharing of specialist facilities can help to promote continuity.

Teachers who lead others within their own school gain confidence in their approach to science and can pass this on. Groups provide ongoing support and informal in-service training. Group discussion about courses helps to save on planning time. There can be a more rational approach to topic or theme development, so that pupils do not revisit the same content area too frequently as they pass from one stage of education to the next. A more thorough appraisal of the facilities and expertise available within the community is possible and schools within the group are able to collect together a resource bank of materials and information.

The most important result of the discussions is an increasing awareness by teachers of the progression of learning in science and technology from the purely intuitive and qualitative approach of the infant years through to an increasingly quantitative and analytical approach during the later stages.

There are other aspects of progression which can be explored. For example younger children should develop, through simple quantitative investigations, an awareness of the influence of science and technology on everyday life. From there it is a relatively straightforward step to activities which are external to the individual and which are concerns of the whole community. (See Box 4.4)

There has been criticism of some introductory science courses in lower secondary or middle schools, because of the tendency to over-formalise the teaching of scientific process and content. This is certainly not appropriate to the full ability range even if some might cope and too often it fails to take account of the experiences in science that students have already gained. In short, secondary schools have not always come to terms with the need for a planned progression through all stages of education.

Box 4.4

The Shanty Town Project

The secondary school is part of a new housing development and the teaching team decided to explore the idea of community.
First, children looked at the local environment and investigated the reasons for the way that it had been developed, investigating its aesthetic and functional aspects.
The teachers wanted to raise the issues of unplanned communities, i.e. shanty towns. The initial idea was highlighted by the staff performing a short play about the problems of a rural family in a third world country and whether they should stay in the country or move to the city to look for work.
Each tutor group then had to imagine themselves as family groups and took on different roles. This involved making decisions and generated material for creative and illustrative writing.
The children then had to build a scale model of a shanty town, using 'Action Man' as a scaling factor.
The science involved looking at health problems inherent in shanty towns. The children investigated the problem of water supply, waste and sewage disposal, disease and diet. Reference materials were brought in from local sources, OXFAM, Christian Aid, WHO and other agencies. Problem solving exercises were provided where children were given information about organisers and their environment. Once these factors were researched the pupils had to make rules which would ensure healthier living in the shanty town.
The home economics department helped with work on how people could provide a healthy diet and balanced nutrition. The children became very closely involved with the project and, after listening to a missionary who had worked in Calcutta, organised various fund raising activities.

Interdisciplinary studies in the early years of the secondary school

To reiterate the aims suggested in Education through Science for the early years, children's interest should be stimulated, maintained and developed, curiosity should be fostered and a growing awareness of the diversity and open-endedness of science should be encouraged. Teachers should also aim to enable children to see the relevance of science to everyday life.

In the primary school these aims can be best achieved through a fully integrated curriculum, arranged around themes, topics, issues or problems, and this type of learning may well also be appropriate to the education of children up to the age of about 13. In some schools an interdisciplinary course of study has been established in the first two secondary years, primarily in an attempt to overcome problems of transition between primary schools and larger, more intimidating secondary schools. Science and other areas of the curriculum have been linked within the same course enabling students to study in depth, but over a relatively short time span, specific themes, problems or topics. Developments can take place within the curriculum which would be more difficult to achieve in a more traditional structure. (See Box 4.5)

The gains and losses of this kind of structure must be formally evaluated because it is essential that the gains from the cross-disciplinary approach outweigh any problems which might arise from feelings of inadequacy in

non-specialist teachers. A particular advantage of this approach is that it readily fosters the idea that the teacher and learner are engaged in joint enterprise, and this does appear to create an environment for effective learning. (See Chapter 3)

Box 4.5

An interdisciplinary scheme for the early secondary years

A team of teachers takes responsibility for the education of a year group of students for a substantial part of the week. They usually have a "home base" set of classrooms in order to establish security and confidence. Within the large timetable blocks the team can organise the work as they see fit.

For the first two years of the secondary school, science shares the sub-school curriculum with English, Maths, Humanities, Music and Drama. The teaming arrangement of teachers and the more flexible use of time allows an integrated approach to the teaching of science and technology and so, within the sub-school, science is not seen as an isolated discipline. The mutual support from the disparate disciplines is seen as essential. In a two year period, it has been possible to show that every subject within the scheme makes a contribution to scientific and technological objectives and, also, that the scientific perspective can help to inform aspects of many other disciplines.

This approach requires a change in one aspect of the role of Head of Faculty or Department, from manager to consultant. The team has to have autonomy of action and must make decisions about course planning and structure in consultation with subject leaders. This has implications for financial

Box 4.6

19th Century Technology

The humanities and science departments met to collate their joint aims for this course and to decide upon supporting content areas. The work was arranged in units, each of which included aspects of both science and humanities, being taught by subject staff from both disciplines.

All the work was placed in a historical context, the first unit being about early man, the inventor and tool user. Students designed and made simple implements and tackled problems of metal extraction, using simulated ores and charcoal.

The second unit went on to look at how man improved his capabilites using sources of power other than muscle. Students designed a windmill or watermill which had some means of power transmission to a pulley wheel. They also investigated gearing.

Other units looked at the utilization of coal in iron and steel production and steam power, and the development of the textile industry. The latter being a case study of how technological change of spinning and weaving by hand to that powered by steam affected economic and social structure of society.

management and the deployment of resources. In order to exploit the potential of cross-curricular links a flexible timetable structure is desirable, so that students can spend longer on science for a particular module or task and make up for this by spending less time during subsequent weeks. The organisation and use of the laboratories has to be responsive to this kind of variable demand and part of the science accommodation is organised as a resource area, visited in the same way as a class might use a school library.

Within this structure modular courses have been developed which cross subject boundaries. "19th Century Technology", for example, is a joint science, technology and humanities course staffed by a team of teachers from these disciplines working together. (See Box 4.6) Another example of a cross-curricular approach is described in Box 4.7.

Box 4.7

Perception

"Perception" is a course involving science and language development teachers. It has a familiar look for science teachers in that it covers the physiology of the sense organs (eye, ear, skin, etc) but it also includes the psychology of perception, self-identity and body language, and the content map moves into areas such as the media, interpretation of messages and the expression of these through language. Thus opportunities are created for students to express their science experiences in the language of everyday life.

Teachers who have worked in this way are convinced that such studies help children in the transition from primary to secondary school. The quality of the science curriculum is enhanced by integration and coordinated planning across subject boundaries, because they allow teachers to view the whole curriculum as experienced by the student. This approach leads to a re-appraisal of courses and a rethinking of curricular issues. In the schools providing the examples in Boxes 4.6 and 4.7, there has been a shift of emphasis from teaching to learning and a feeling that learning within mixed ability groupings has become more effective.

Courses linked with the community

People do not always agree on how schools should relate to their local community. There are various groups of people legitimately interested in the school and their involvement should be encouraged. These groups include students, parents, local residents, and business persons and their representatives. Schools should aim both to serve the community and to make use of the resources it can offer them.

Science occupies an important place in our culture and therefore science education should not be an activity which is complete when a person leaves school. There should always be the opportunity for adults to return to a study of science at intervals during their lives. Some community schools have sought to combine the needs of full time school students with those of adults. Within this context, two types of course may be identified. The first is the recreational or special interest course, where scientific and technological knowledge and skills can be used to enrich leisure interests and the extension of self sufficiency, and the second is the course with a specific vocational basis. The latter type is discussed later in this Chapter under the heading "Courses linked with industry".

The leisure and self-sufficiency type of course is closely related to science courses designed in recent years for less able students in fourth and fifth years. They aim to provide experience at first hand through experiment and to capitalise on the interest and motivation arising out of the student's perception of the relevance of the work to everyday life.

Some of these courses have been developed to include quite complex and abstract concepts, making them appropriate for mode 3 O-level examination certification. Clearly many of the themes in such modular courses encourage leisure interest among people who will later find they have an increasing amount of leisure time to fill. This kind of study might well be appropriate for adult members of the community and many young people would find it an enriching experience to work with older enthusiasts. In some schools adults are able to join classes alongside the students and take advantage of this more flexible and broadly based approach to science education. (See Box 4.8)

Box 4.8

SCIENCE FOR LIVING

CAR MAINTENANCE

ELECTRICITY IN THE HOME

HUMAN BIOLOGY AND CHILD CARE

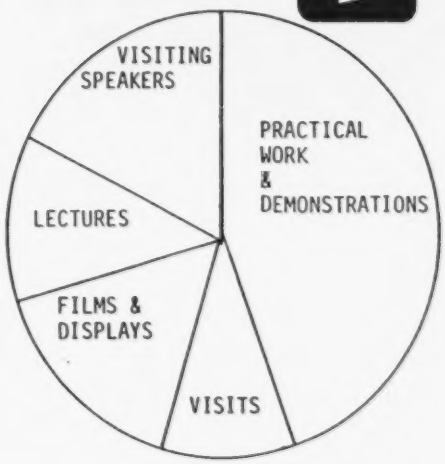
FIRST AID

LOW BUDGET COOKING

MODERN MATERIALS

CONTENT OF THE COURSE

Classes will be held for 2 hours per week from September 1983 - July 1984.
No previous experience or qualifications are necessary and there is no exam.



The local community of a school provides a rich resource for science teachers. (See Box 4.9)

Box 4.9

One school devised a project on the difficulty of cleaning windows in a local high-rise block of flats.

Cleaning Windows Project

Science & Technology

MEMO

To: All 4th Year Students.

Ref: Common Core - Civil Engineering Project.
Please read this paper - see what you can do about the WINDOW CLEANING PROBLEM.
You haven't got long - you better get to work.

JTS.

Dear Sirs,

In connection with your role as Consulting Engineers specialising in Building Services we request that you prepare for our Client (Bushport & Co Ltd.) a design for window cleaning apparatus at the Howlett Towers Hotel, Dracupville, Gwynne's County.

Attached are our client's instructions detailing the work they want done. The scheme design is competitive and the firm whose scheme is approved will be awarded a contract to carry out the detailed design and supervise construction.

Yours faithfully,
Ivor Problem
Managing Director

PROJECT INSTRUCTION

Please prepare a scheme comprising a report with drawings and/or models to assist the client and convince him of the quality of your design.

The report should include:

a) Alternative schemes considered.

b) Reasons for choice of one scheme in particular.

c) Any design features not shown on drawings.

d) Construction method details.

e) Materials recommended.

f) Approximate quantities of materials.

The scheme should be available for appraisal in six weeks time for presentation to the client in the following week.

Schools should train students to look for the effects science has had on their immediate surroundings. Not only does this make students more observant but also makes them much more aware of science as an all-pervading aspect of life that extends far beyond the school laboratory. This practice is commonly used in rural schools, where students follow nature trails, but has also been adopted in one inner city school where a chemistry trail has been devised. (See Box 4.10)

Box 4.10

A Chemistry Trail

In 20 stops the trail takes students around the school and its immediate neighbourhood examining items of interest in the chemical environment.

The first stop emphasises the multi-cultural nature of chemical symbols. Stop 2 looks at the chemistry of cement which can display some good acid/base reactions. We then consider air pollution, noting the use of lichens as pollution indicators. The kerbstones in the street are made of granite, the neighbouring church of sandstone: the effect of pollutants on these is contrasted. We note the use of bricks for housing. Conveniently, the council has provided a bin of salt for the roads just outside the school. Around the school can be seen several examples of metallic corrosion (both by differential aeration, and bi-metallic corrosion): mainly the result of serious errors on the part of the builders and/or architects. The swimming pool is a rich source of fascinating and little known chemistry (including neutralisation on a large scale). Finally, a walk of 200 metres takes us to one of the sites at which the Water Authority monitors river pollution.

Initiatives linking schools and industry are now very common. They range from very small scale links between particular schools and firms, through to major national schemes such as the TVEI. (See Box 4.11)

Box 4.11

An example of a link between a school and a local firm

A partnership has been formed between a school and a neighbouring electronics company. This has resulted in a course which is appropriate for both older school students and also for the company's employees. It began with the school approaching the company for help in establishing a school-based electronics course. As a result of discussions on course content and resourcing, the decision was made to set up a joint enterprise. Employees were sponsored for evening class attendance and school students could enrol for the same course but did not have to pay a fee. This type of scheme may be extended so that some of the sessions take place at the employer's premises as well as the school. In this way the school gains an understanding of the needs of employers in particular industries and are helped with resourcing, both in terms of materials and advice on the choice of equipment and supplier.

Students on such courses tend to be considered favourably by employers for jobs because, through employers' networks, others come to hear about the courses and their aims. The courses flourish because of the establishment of a cooperative and constructive partnership, a way of progressing which is strongly recommended in Education through Science. It is relatively easy to establish this kind of partnership between new industries and schools where there are very few preconceived notions on both sides, but with more traditional industries distrust may still exist. Industry asks for a sound basic education and tends sometimes to dismiss new courses which diversify interest. They think of them as "trendy" and lacking in the skills training that they demand. However, schools now have a new opportunity to create a constructive dialogue with industry through TVEI.

Schools must try to establish a balance in the curriculum between the explicit perceived needs of employers and other representatives of the local community and the future needs of individual students in their adult life. Present day students will have to be more flexible in their views and approach to work than ever before. They may have to be prepared for rapid changes in technology and to move to different parts of the country in order to pursue a new career. Such a change in career may happen more than once in their working lives. So, while it may be desirable to work very closely with local industry, it is also important to maintain a broadly based science curriculum which does not specialise too early in the school programme thus shutting too many doors to possibilities at 16+.

Many LEAs have produced Resource Guides to help to bring together schools and local industry and commerce. (See Box 4.12)

Box 4.12

An Introduction to a Resource Guide

This Resource Guide has been compiled as an aid to schools wishing to involve the local economic community in their teaching. Within its covers we have tried to include as much information as possible about education, industry, the trades unions and local community projects. Because of this we hope that it will be of interest to a wide audience.

As a document, this Guide can only help in the first stages of working with the local community. Real success can only develop out of a partnership between the local economic community and school. There is not enough room in this Guide to include a detailed discussion of the ways in which this relationship can be developed. For this reason it is important that schools discuss their work with the Divisional Industry Schools Coordinator (DISCO).

Finally, in order to keep this guide up-to-date we need to know about any school-industry links that take place locally. Please let the DISCO know of the results of your enquiries.

In planning recreational and vocational courses for students in their final years at school, some schools have found it useful to have a new look at the timetabling structure. It is too easy to become locked into a pattern of a regular weekly ration of study organised on a yearly rotation. An alternative, however, is modular courses with short-term specific goals, where success is measured in terms of credits and profiles. This more flexible approach is

also more appropriate for adult learners because they may well have a great deal of leisure on a short term basis because of unemployment. Moreover, a student who is committed to a short period of study at weekly intervals for a long time (perhaps a year or more) may find it difficult to sustain interest. Skills training is often more effective if it takes place over a short but intense period of time rather than at infrequent intervals.

Many schools now operate work experience schemes for students in their final year. Some schemes provide for work experience at regular weekly intervals but others, perhaps more effective, offer periods of block release of a week or more. Very careful liaison and monitoring is needed to ensure that both students and the firms providing the experience are achieving their objectives and getting appropriate support. It is quite possible, provided sufficient research and preparation is carried out in advance, to organise science based work experience projects and these can be valuable not only for school leavers but also for able boys and girls who intend to pursue higher education courses. Some of the water boards have, for example, been very helpful in this respect.

There is urgent need for consideration of the needs of non-academic students staying on at school, after they have reached the statutory school leaving age. There is a multiplicity of training and educational agencies concerned with this age group, but it is not easy for ordinary teachers to find their way through the mass of complex information about them. The ASE Education Conference 1984 was concerned with this area and discussed CPVE, proposals put forward by BTEC, etc. Useful guidance can often be obtained from the SATROs.

Summary

This chapter has examined current examples of good practice where primary and secondary schools have cooperated. This liaison has led in some cases to the restructuring of content areas and evaluation and reformulation of the learning strategies employed by both sectors.

Local communities are also discussed. Not only do they have an interest in the outcomes of the educational process in schools but they can provide valuable resources of expertise as well as more tangible things. The chapter describes examples of courses that have been set up as part of community education programmes or in cooperation with local employers. Examples are also given of course materials that use the local physical environment to illustrate scientific concepts.

CHAPTER 5

THE WHOLE CURRICULUM PERSPECTIVE

This chapter seeks to show that there is a need to think beyond the conventional timetable barriers when searching for curriculum models in science. The whole curriculum includes not only the academic, formally taught material, but also pastoral aspects, the aspects exemplified and encouraged in the school and all that is implied by the phrase 'hidden curriculum'. A holistic approach is already seen in many primary schools but little prominence may be given to science.

In secondary schools science is commonly perceived in isolation from other subjects. Traditionally the science curriculum consists of physics, chemistry and biology, each being taught separately. These are respectable academic subjects when viewed in isolation and this kind of organisation is consistent with an analytical approach to knowledge. However it is questionable whether such a compartmentalised approach makes sense in the minds of young people. There are other reasons too why a more integrated approach is preferable, including the needs of society in a time of rapid and unpredictable change. Why should the traditional subject-orientated approach suddenly become appropriate in the secondary school when it is so rarely used in the primary school? Moreover, there are recognisable scientific experiences offered in other subject areas which, in current practice, are divorced from the main thrust of science education. Serious consideration should be given to the establishment of a coordinated approach across the curriculum. There is no reason at all why such an approach should not respect traditional subject divisions but it should transcend them. It should also, as has been argued in Chapter 4, take account of the community and the needs and aspirations thereof.

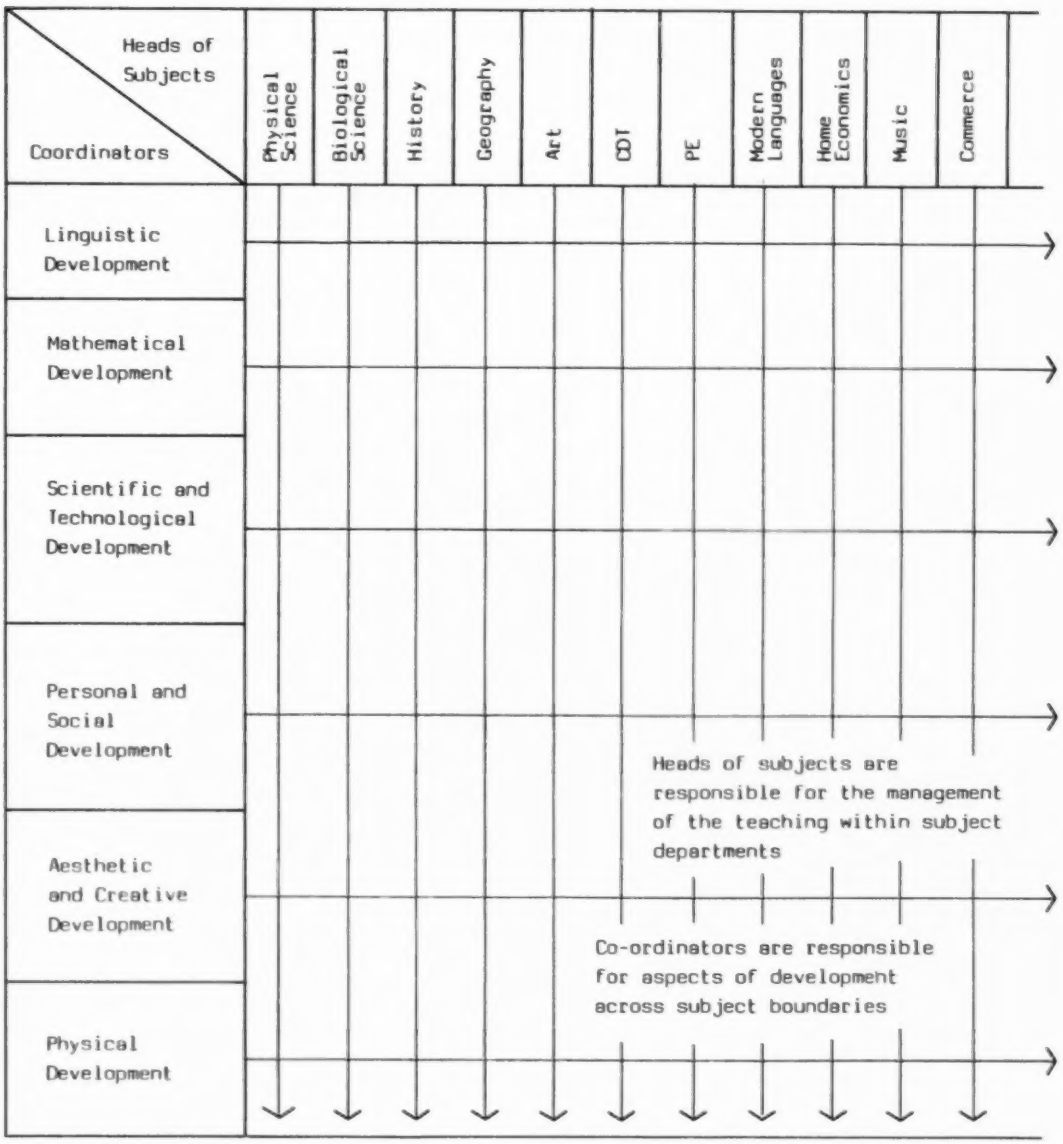
Some schools have already successfully experimented with alternative middle management posts to enable staff to have an overview of aspects of the curriculum which cut across subject boundaries. As well as subject-specific responsibilities within a department, they also have coordinating roles. Such a structure might include a coordinator for science or science and technology.

This however is not the only solution to the problem of lack of coherence and isolation within the curriculum. Its success depends very much upon the strengths and skills of the coordinators and indeed upon their idiosyncrasies. The whole curriculum should be the concern of every teacher. A broad, balanced science curriculum should be seen within the context of a broad, balanced general education and each teacher should be aware of the total package that is being prepared for and offered to the students. Job specification can sometimes have the unfortunate spin-off effect of appearing to absolve other teachers from certain general professional responsibilities. Clearly this has important implications for staff development and training.

Publications of the Department of Education and Science (DES), for example The School Curriculum (1981), and the Schools Council in The Practical Curriculum (1981), while recognising the importance of a holistic approach, fall into the trap of defining the curriculum in subject terms. Thus a broad curriculum is seen as nothing more than a range of disparate subjects - English, mathematics, science, a subject from the humanities, a craft, perhaps, physical education, religious education, etc; the list varies in length and diversity according to the fashion of the moment. This is a very limited perception. What is required is a deeper analysis in terms of learning experiences. This technique has already been explored in a slightly narrower context in Chapter 3.

Box 5.1

An Organisational Framework using Curriculum Coordinators and Heads of Subjects



Learning experiences should be constructed so as to take account of students' needs and not only the entry requirements of the professions and higher education or the perceived needs of the nation. Students have to be helped to develop their own identities so that they can become autonomous learners and decision makers and feel a sense of confidence and success in their personal relationships. Education through Science has something to say about this:-

> "Science, like any other discipline, provides a means whereby the individual can organise his or her own concepts and attitudes, classify experience and communicate with others."
>
> "Science ... requires the individual to come to terms with a particular approach to issues and problems."

There are many approaches to cross-curricular science education; two that have been advocated in this report and elsewhere are problem-solving and work built around current and historical issues. Most problems and issues are not subject-specific in terms of either context or content or indeed the processes which might most appropriately be applied. Aspects of science can and should be experienced outside timetabled science lessons and areas not traditionally associated with science should be encountered within them.

This sort of diversity and interrelationship should be welcomed by teachers. The contexts of natural resources and energy, their distribution, exploitation and conservation are relevant in, for example, both geography and science, and the study of science in a historical context is often extremely appropriate. Heat transfer and bacteria are normally content areas covered in both science and home economics, meteorology in both science and geography. History as well as science makes use of the processes of data collection and analysis and of course mathematical skills are often used by scientists. Not only is mathematics essential in scientific investigations of any sophistication but such investigations provide excellent opportunities for students to see mathematics being applied and good science teachers can help to nurture mathematical concepts through the results which occur.

Box 5.2

Science/Home Economics Cooperation

HOME ECONOMICS WORKSCHEMES

Year: One **Term: Two** **Sequence: Transfer of Heat**

(Lesson 1: Based on Video "Science all round - Transfer of Heat")

Lesson 2: (abbreviated version of original plan)

Activity:
Investigating the effect of cooking at different levels in the oven, by making a number of small cakes.

Teaching Approach:

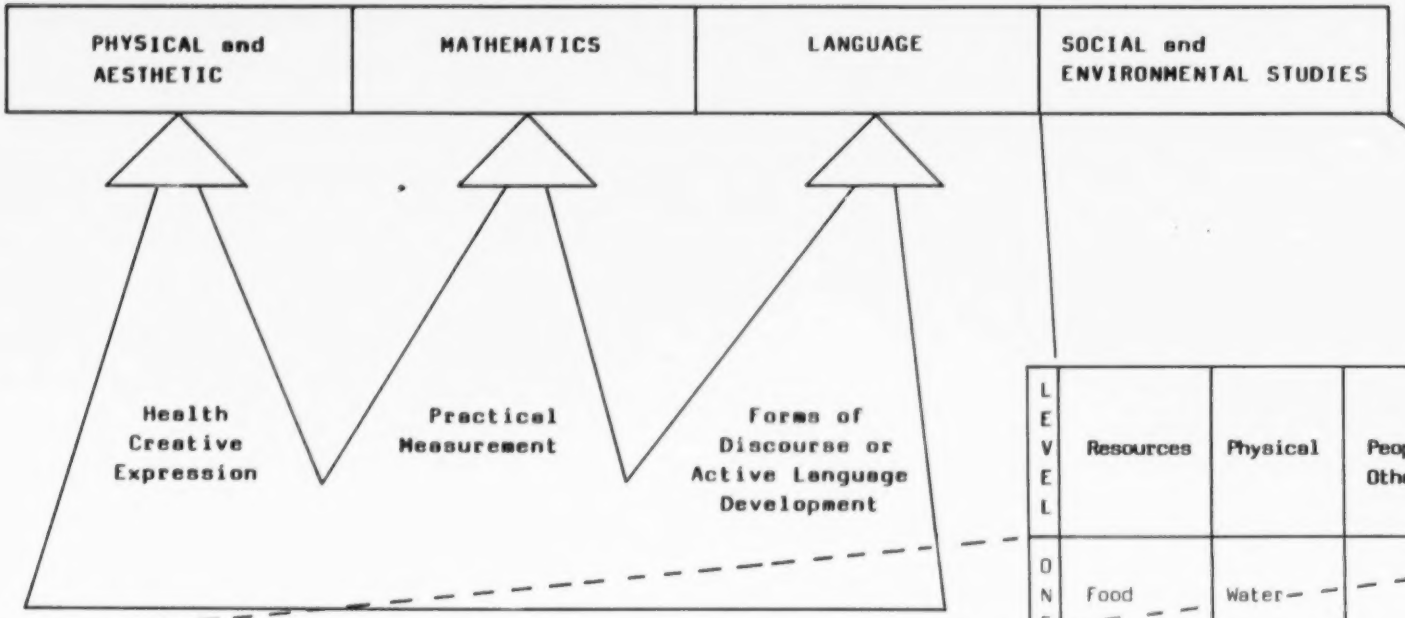
Introduction:	class discussion to plan activity as a scientific experiment. - identify variables etc. - assign tasks to each group so that class obtains a range of results
Practical:	pupils carry out assigned tasks
Written work:	pupils compare results. They write up the experiment including the interpretation of the results.

Science Department Input:

1. Course planning meeting attended by a science teacher.

2. Science teacher joins class towards end of lesson to assist pupils to write up experiments, following correct procedures.

Box 5.3 Science in the Whole Curriculum



	Food	Water	Animals	Making Maps	Space	Me and My Family
Living Things & Their Environment	Taste/smell Food prefs. Diet Microbes	Need for water by by living things	Movement Adaptation Life Cycles Teeth Hibernation		Air	Growth and Measurement
Materials & Their Characteristics	Cooking	Rusting Floating Washing/ Drying	Camouflage Body Coverings			
Energy Interactions	Energy sources	Heat Measurement Erosion	Heat Loss		Balloon Rockets Gravity	

LEVEL	Resources	Physical	People of Other Lands	The Environment	Mapping
ONE	Food	Water		Animals	Making Maps
TWO		Weather	Family in Europe	Minibeasts	
THREE	Building Materials		People in 'Third World'	Plants	Using Maps
FOUR	Fibres and Fabrics	Air and Earth			

Language skills are important right across the curriculum and science can be an important vehicle for language development. Scientific writing requires transactional language skills which need special teaching, but there is also a place in science education for the more creative writing traditionally associated with English and the humanities. Oral and listening skills can also be encouraged and enhanced in science lessons. Science lessons present important opportunities for students to learn advanced reading skills. These skills are an essential part of a student's scientific development too.

It is not sufficient only to recognise overlap between subject areas, nor just to broaden the work within a subject so as to include contexts, content and processes which are new to it. Learning strategies cannot be employed in isolation but must be developed as part of a whole school policy. There are a number of different ways in which this can be tackled but they all involve organisational change. This is an issue that schools must face and discuss before any significant progress can be made.

There is a wide spectrum of methods for providing courses across the curriculum. These range from the coordination of the exchange of material resources, to the provision of integrated courses taught by teachers from different disciplines working as a team. Schools that value cross-curricular teaching often create coordinator posts to replace the more usual middle management structure. (See Box 5.1) Coordination at its most limited may only involve the input of resources into another area. Science departments can sometimes help other departments by providing apparatus or teaching materials or by carrying out a few experimental activities as demonstrations.

Another form of cooperation that maintains the integrity of subjects while reducing insularity involves the input of expertise into other subject areas. The expert can provide teaching guidelines and technical information or, better still, go into lessons to assist the regular teacher. (See Box 5.2).

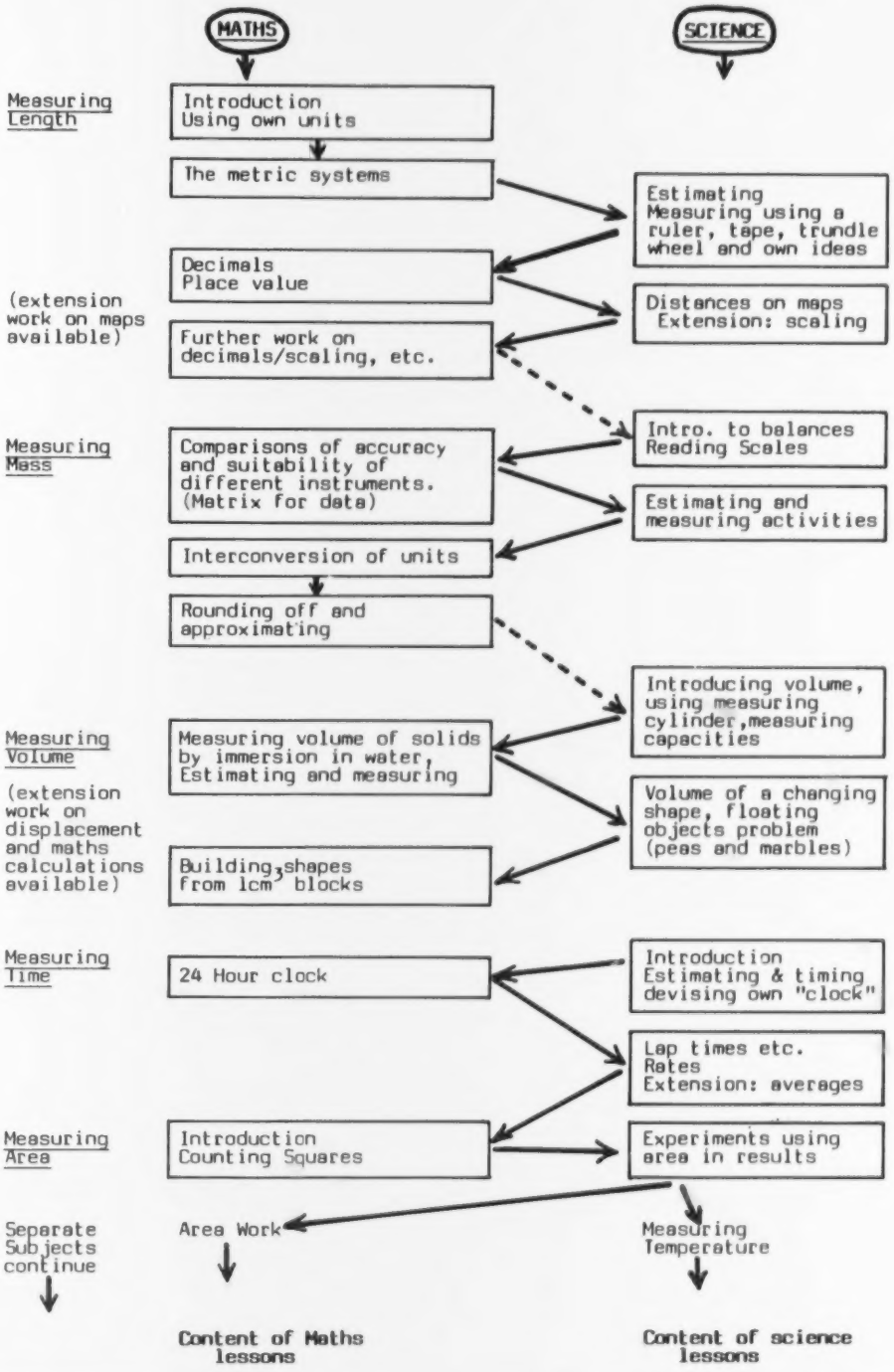
Planned sequencing might result from an analytical overview of the whole academic curriculum. Two or more departments or subject areas may wish to build on the knowledge and skills imparted by each other. This sort of interactive work will only make sense to the students if the teachers have carefully planned the order of presentation in their own subjects. (See Box 5.3)

Some of the themes of scientific education arise in many other subjects. Health education and electronics are good examples. Systematic planning and coordination across the curriculum can ensure continuity, sequence and integration as described in Chapter 3. Gaps between subjects can be bridged, consistency of approach maintained and duplication avoided. Tasks of this nature can be delegated by senior staff to younger enthusiasts, thus combining in-service training and professional development. Yet another possibility is to set up a cross-curricular course to run alongside the traditional subject options and an example of this approach has been described in Chapter 3.

A more radical approach to cross-curricular work is to set up truly interdisciplinary courses. These may be limited to discrete topics where different subject areas agree to combine their teaching time, in order to provide a coordinated teaching programme. If, for example, the maths and science teams combine to teach a unit on measurement, there is a good chance that the students will appreciate that they are studying measurement as a topic in its own right rather than 'measurement in maths' or 'measurement in science'. (See Box 5.4) This method can be extended so as to provide year-long interdisciplinary courses. An example including science and technology has been described in Chapter 3. Finally, yet another alternative is provided by the integrated team-teaching organisation described in Chapter 4; it has been successful in the early years in a secondary school but has yet to be proved feasible in later years.

Box 5.4

Unit Measurement


MATHS
SCIENCE
Measuring Length
Introduction Using own units
The metric systems
Estimating Measuring using a ruler, tape, trundle wheel and own ideas
Decimals Place value
Distances on maps Extension: scaling
(extension work on maps available)
Further work on decimals/scaling, etc.
Intro. to balances Reading Scales
Measuring Mass
Comparisons of accuracy and suitability of different instruments. (Matrix for data)
Estimating and measuring activities
Interconversion of units
Rounding off and approximating
Introducing volume, using measuring cylinder, measuring capacities
Measuring Volume
Measuring volume of solids by immersion in water, Estimating and measuring
Volume of a changing shape, floating objects problem (peas and marbles)
(extension work on displacement and maths calculations available)
Building shapes from 1cm³ blocks
Measuring Time
24 Hour clock
Introduction Estimating & timing devising own "clock"
Lap times etc. Rates Extension: averages
Measuring Area
Introduction Counting Squares
Experiments using area in results
Separate Subjects continue
Area Work
Measuring Temperature
Content of Maths lessons
Content of science lessons

In any development which involves the breaching of subject barriers, attitudes are crucial. The best kind of coordinated curriculum develops where there is a genuine affinity between the staff concerned and excellent examples of cross-curricular work exist within the most conventional of organisational frameworks. They have emerged because two or more people have perceived a

common problem or interest and done something about it. This sort of initiative does not depend upon structures or upon pressure from above. To capitalise upon it is excellent but to rely upon it leaves a great deal to chance. Such opportunistic developments must be formalised if they are to have any permanency. The existence of a carefully designed organisation for change does not preclude spontaneous development and indeed it could even facilitate it. A particular style of leadership is essential to encourage this. The leader must encourage and build upon initiative, providing the necessary climate for growth.

A more systematic approach is to scan the work schemes of all subject areas and to identify the scientific and technological elements. The whole picture can be presented as a matrix with one axis representing school years and the other the various subjects. Into the boxes so formed are placed the elements of scientific learning to produce an overview. Anomalies and omissions are thus highlighted and the matrix becomes a springboard for curriculum development. It can be related to the taxonomies of factual knowledge, concepts, skills and attitudes discussed in Chapter 3. The learning experience matrix described in that chapter is derived in a slightly different way but provides a useful comparison.

Few schools have actually completed a full systematic analysis of their curriculum, but just making a start soon leads to opportunities that can be developed long before the process is complete. However it is wrong to rely entirely upon an opportunistic approach.

Summary

Scientific concepts, contexts and processes occur across the curriculum. It is important that teachers are aware of exactly where the cross-curriculum links are to be found. Once these links are established, work can be developed between traditional subject areas and links strengthened in a variety of ways:

(a) Completely linked work : subject areas agree to combine teaching time and teachers to provide a coordinated or interdisciplinary teaching programme.

(b) Planned sequencing : subject areas agree to build upon knowledge and skills imparted by each other in a sequenced way, rather than haphazardly.

(c) Thematic spirals : elements of scientific education arise in many different subjects. Health education is an example where work can be planned and coordinated across subjects and years, to ensure that students experience an effective learning programme up to 16.

(d) Input of expertise and for resources: teachers may be able to provide guidelines on teaching methods or scientific concepts. They may even be able to go into other lessons at appropriate times. Science can also help by providing apparatus and materials that can be used in experimental activities in other lessons.

To build up those links in anything other than an ad-hoc manner requires organisational change. Schools need people who are coordinators of science across the curriculum. In this way not only concepts but also learning strategies, teaching methods and attitudes can be developed as a whole school policy.

CHAPTER 6

SOME FURTHER THOUGHTS

The working party hopes that this report will be judged in in the context of the ASE policy statement, Education Through Science. The reader is referred to the summary of recommendations and proposals in that document and especially recommendations 1 to 23. Our report is an attempt to suggest ways of implementing these proposals. We think that Education Through Science was an important step towards the modernisation of the science curriculum; a curriculum which we hope will be accessible and useful to everybody and not be confined to a cultural, social or professional elite. If Education Through Science tells us what needs to be done and why, then our report can, we hope, give some guidance on how it can be done.

Recent DES publications emphasise the importance of reviewing and evaluating the curriculum and its management. The DES policy statement on science, (Science 5-16: A Statement of Policy), endorses the notion of balanced science for all and gives firm and unequivocal guidance on the amount of time it should occupy in the timetable for the five years of compulsory education up to 16+. The recommendations correspond closely with the assumptions we have made in writing this report, namely 10% in the first two years, 15% in the third year and 20% in the final two years. Few who have followed the debate will be surprised by this but it is likely that many will be dismayed by the radical changes that are proposed for the structure of the curriculum and its associated pedagogy, especially the very clear move towards total or partial integration.

We welcome the proposals, believing them to be logical consequences of the position ASE has adopted. What worries us intensely though is the naive assumption in some political quarters that we can march into this brave new world without a major reassessment of the resources and expertise available to carry out the necessary reforms. At present teachers have neither the time nor the support in terms of training and resources to be able to go forward in this way. Their workloads, both at present and even more so in the future if we are to move forward, are unrealistic. It is therefore not surprising that some take refuge in a blinkered resistance to change of any kind. Unless LEAs can improve staffing levels so as to enable schools to timetable consultation, INSET and curriculum development, there is a real danger, not only to teacher morale and the efficient running of schools, but even to the very social and cultural fabric of the nation.

The Secondary Science Curriculum Review, of which the ASE was the initiator and remains a major sponsor, is committed not only to making proposals for change but also, more importantly in our view, to detail their cost implications. We think that such an approach is long overdue and sincerely hope that both central and local government will feel a moral obligation to take the findings seriously and to act accordingly. In short the issues must not be fudged and essential funding must be found from somewhere.

Our report advocates radical changes in the approach to teaching and learning and suggests reasons for change. (See, for example, 'Balanced Science for All' in Chapter 1). Will it prepare people effectively for a world of rapid social and technological change, much of it unpredictable? Will it assist people in any way to cope with what might well be a very threatening social environment for those educated in a traditional way? Will it provide education for capability? These are questions which we hope our readers will consider.

"The curriculum of a school is the whole set of experiences by which pupils are educated." (Holt, 1980.) No part of the curriculum should be planned or studied in isolation from the rest. We have suggested, in our final chapter, a number of strategies for co-ordinating science and technology across the curriculum. Clearly, if our philosophy is accepted, a science department (or any other department for that matter) can only plan effectively for change by working in close association with other colleagues. Head teachers and senior management teams in schools, together with their governing bodies, obviously have an important role to play in this interdisciplinary process. There are risks involved in any proposals for change. To recognise these risks should not mean that the need for change is ignored. Too often in the recent past our teaching profession has erred on the side of caution and our paymasters, by their financial parsimony, have provided us with a ready excuse and rationale for our conservatism and inaction.

We are encouraged by some recent developments, especially the DES 4/84 courses, for heads of science departments for example, and the prospect of Educational Support Grants. We hope that both these initiatives will be put to effective use. Unfortunately neither of them, or so it seems at present, will do much by way of releasing teachers on site and in normal working time to cope with the urgent problems of innovative timetabling, curriculum development, and cross-curricular consultation, planning, joint action and management of change. Essential INSET for junior staff (and also those more mature and experienced staff who need support and encouragement as their roles change and their expertise becomes outdated) are also best carried out, at least in part, by a regular 'drip-feed' technique within schools. These aspects have important implications relating to the teaching loads, not only of staff receiving training but also for senior staff, not least heads of department, who should be expected to plan and implement them.

We think that urgent priority should now be given by those in a position to influence priorities and funding to the issues discussed above.

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